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R.E., LL.D., F.R.S.L. & E., F.R.A.S., F.G.S., M.R.I.A., ETC.

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TOGETHER WITH

A SKETCH OF THE ORIGIN AND PROGRESS

OF THE ORDNANCE SURVEY OF GREAT BRITAIN

AND IRELAND;

A WORK WITH WHICH GENERAL COLBY WAS CONNECTED FOR FORTY-FIVE YEARS.

BY

LIEUTENANT-COLONEL J. E. PORTLOCK,

R.E., F.R.G.S. & M.R.I.A., ETC.

SEELEY, JACKSON, & HALLIDAY, 54, FLEET STREET
LONDON, MDCCCLXIX.

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ROYAL OBSERVATORY, GREENWICH,

LONDON, S.E.,

1869, *June 9th.*

My Dear Madam,

The number of occupations which have pressed upon me about the time of the Annual Visitation of the Royal Observatory have made it almost impossible for me to write a private letter. This is the explanation of my long delay in answering your letter of May 22.

I have perused, with some attention, Colonel Portlock's Memoir. I need not say that it contains much with which I was not sufficiently acquainted to have been able to write anything with certainty. But all that I do know is given with great accuracy and fidelity, and a generally correct idea of the remarkable man who is the subject of the Memoir will be obtained by reading it.

I do not remember how my acquaintance with Colonel Colby began.

We both were members of the Board of Longitude, which was dissolved in 1829 (I think), and it is probable that our intimacy commenced then.

It could not be later when I received a call from him at Cambridge (I suppose at the Observatory), when he was on his way to Ely, upon business of the Survey. Subsequently I saw him very frequently, and on some occasions which were almost official; in inspection of Ramsden's Sector at the Tower; in preparing the Sector with which my name is connected; in arranging Tidal Observations; in preparing for determination of the Longitude of Valencia; twice or oftener in examining the System of the Phœnix Park Office; and at many other times.

At one of my Irish visits, I had the happiness of enjoying the hospitality of Knock Maroon Lodge, and in later years, when Colonel Colby was for a long time fixed in London, I and my family had the gratification of receiving him very often at our Sunday dinner at Greenwich. We can all bear testimony to his kind and social disposition; his appearance was always a source of friendly pleasure to us.

I was often struck with the peculiar adaptation of Colonel Colby's talents and habits to the great work which he directed, and the great

system which he principally created. With the scientific geodetic problem before him he was familiar.

On the grand points of execution, such as the large-scale triangulation (I may well use that epithet for a triangulation which described the length of Ireland in three steps, and its breadth in two), he was clear in his own judgment, and decided in his provisions for carrying them out.

On the detailed points, such as local surveys, mapping, engraving, engagement of local assistants, &c., of which the execution naturally fell to other persons of all ranks, he was most precise in arrangements on the broad scale, and at proper times most exact in watching their general success.

The order of his offices was admirable.

His attention to the accuracy of instruments of every kind—personally for those used in the grand survey—systematically for those used in the details—was very great. And all this devotion of himself to his great work appeared to be wholly unselfish.

I never heard a word from him which implied that he was looking abroad for personal glory, or for any expression except the recognition of his results—as producing a scientific survey superior to any that had ever been made, and a cadastral mapping to which no other, I believe, can be compared. He was most liberal in his praises of the officers

subordinate to himself by whom the scientific details were more immediately managed.

I hope that these short statements may assist to perpetuate an impression which, as I know, was felt by others as well as myself.

I am,

My dear Madam,

Yours very faithfully,

G. B. AIRY.

Mrs. General Colby.

MEMOIR OF THE LATE MAJOR-GENERAL COLBY.

When we turn from the contemplation of great actions, either in civil or military history, to an investigation of the causes which have led to their performance, we are too often doomed to experience the disappointment of finding the motive-springs of brilliant acts, in themselves, mean and sordid. Were it, however, the object of this memoir to describe the moral rather than the intellectual man, the character of General Colby might be subjected without danger to the ordeal of such an inquiry, as few men were so free from the impulses either of avarice or of ambition. Affecting no contempt for the pecuniary remuneration of his services, and rightly considering the labourer worthy of his hire, he was always willing to apply what he derived from the service to its advancement; and hence it was that neither he nor any of his officers or assistants ever thought of calculating personal expense when it became necessary to push forward the work confided to their care. If, therefore, General Colby considered that officers of the Survey should

be well paid, he was influenced, not by a spirit of accumulation, but by a desire to afford them the means of moving and acting with energy and effect under all circumstances. In like manner, though, in his early life, he was not indifferent to honorary rewards or distinctions, especially those of a scientific character, it cannot be said that at any time the desire of obtaining them exercised a powerful influence on his mind; and when, in later years, his affections became domestic in their tone, and were centered in his home and linked to his wife and children, he appeared absolutely to despise them.

A contempt for worldly honours, and an indifference to wealth, are often cited as characteristics of a great mind; and yet qualities so undoubtedly noble are on the whole more suited to the quiet philosopher than to the active man of business. A sense of duty will impel a man to do and to suffer much, and the love of a particular pursuit will render him regardless of difficulties, and blind to danger, just as the botanist will seek the rare plant, or the entomologist the wished-for insect, in the deadly marsh, the impervious forest, or in the burning desert; but when so much has been done and suffered, he who was unmoved by the apprehension of corporeal pain and danger will shrink from the mental torture of other men's criticisms, unless urged forward to the publication of his labours by the hope of attaining either wealth or honours for the present, or an undying fame for the future. The want of this stimulating and supporting prin-

ciple induced in General Colby an indisposition to publish the details of the Survey, and a morbid apprehension of criticism; for, though no one was more prompt and energetic in action, no one more assiduous and skilful in observing, no one more confident in his own personal resources, he yet, after the death of General Mudge, gave the public no account of the Survey, and allowed the published maps to continue the only records of its progress and excellence. It is impossible not to regret this fatal error, as it has materially tended to alienate the Ordnance Survey from the good feelings of the scientific public, and has thrown over a work, with which not merely every scientific, but also every practical man, should be familiar, an air of official mystery and seclusion. If, however, General Colby neglected the means of ensuring his own personal fame, he was nobly disinterested in respect to the services, merits, and rewards of those acting under him; and whoever has studied human nature, and observed how many a man of great talents has laboured all his life in the shade, whilst a superior in rank has been lifted up, as it were, upon his shoulders, to eminence, will appreciate the high-minded manner in which General Colby bore testimony to the merits of his officers, and permitted them on several occasions to publish portions of the work rather as principals in it, than as assistants: a generous line of conduct to which must be ascribed the first successful steps in public life of Drummond, Larcom, Dawson, and others; the first opportuni s

of exhibiting those talents which have subsequently placed them in important public stations.

Some portion, indeed, of the delay in publication which it has been necessary to notice, was the result of the early distinction which several of General Colby's officers thus acquired, the preparation of part of the work for publication having been relinquished by Captain Drummond on his appointment to an important political office; and, subsequently, by Lieutenant Murphy, on his becoming an associate in the scientific and arduous Euphrates expedition of Colonel Chesney. In respect to temper, General Lewis and his other contemporaries have spoken favourably of General Colby, who had the great merit of having conquered himself, and reduced a naturally warm disposition to such discipline and order, that few could say they had ever seen him lose his self-command: and if he ever did so, his usual equanimity was disturbed but for a moment, as may be judged from the following characteristic anecdote: —"The writer of this memoir had prepared the great instrument for observation on Slieve Donard early in a morning of August, 1826, and had watched for some time the light as it slowly broke behind the dark mountains of Cumberland, when observing the outline of Sca Fell gradually assuming a distinct shape, he called up Colonel Colby, who instantly came to the Observatory and directed the telescope on the mountains. The distance was 111 miles, and the difficulty therefore of accurately bisecting the object very great. Alternately, however, Colonel

Colby and the present writer attempted to achieve the task, and at length Colonel Colby was on the point of successfully finishing his observation, which would have been a geodesical triumph, as including the longest side of a triangle ever attempted, when an officer on entering the Observatory accidentally struck his elbow, and threw the telescope off the object. A momentary ejaculation of anger escaped his lips, but though he could not again succeed, and the object was, therefore, lost, he never afterwards alluded to the subject." In manners and habits, he was singularly simple and temperate, being as much at home and as satisfied on the mountain top with the most ordinary fare, as in comfortable winter quarters with corresponding good cheer. In London, when a bachelor, he dined very often at the clubs of scientific and literary societies, being a member of almost every one then established; but all who served under him at that time will remember to have, on some occasion, met him running rather than walking (for such was his custom) along the street on his return from the Ordnance-office to the Tower, and to have been greeted by the hearty invitation, "Come back, my boy, and take a beef-steak with me" (which steak often expanded into excellent fish and a good fat turkey), or "Come to the lecture at the London Institution, and let us take a chop by the way;" simple festivities, unostentatious hospitalities, which will never be banished from the recollection of those who shared them. When married, his hospitality was equally hearty

and equally unostentatious; and those who were privileged to become occasionally inmates of his house, must warmly remember how completely at home and how happy they were made in that well-ordered and peaceful family.

In person General Colby was rather short, and possessed of a singularly nervous and elastic frame, which no fatigue could overcome. Exposed almost bare-breasted to the storm, he appeared unaffected by the bitter blasts of winter, and day after day he persevered in walks over mountain districts which no ordinary strength could have mastered. His personal deportment was not perhaps dignified, but there was about him an air of will and determination which secured for him the obedience and respect of his subordinates; and when called upon to submit to a painful inquiry into the state of the Irish Survey, he exhibited that higher dignity of the mind which is manifested by a calm self-possession and a maintenance of self-respect under very irritating circumstances; or, in other words, by the possession and display of that steady firmness which makes a man superior to the world. To his character as a husband and father, his bereaved widow and children, who prized so highly his affection whilst living, and who now so bitterly deplore his loss, can alone bear fitting testimony, though many have witnessed with gratification the playful cheerfulness and the unruffled calm which pervaded his domestic establishment, and told, in language low but deep, that discord was there ... welcome guest. His intercourse with men at

large was more open to observation, and in it, as in the conduct of most erring mortals, there was much to admire and something to blame. His tastes led him to prefer the company and friendship of men of science; but, in judging of their relative excellence, he was sometimes led to under-estimate it by over-strained prejudice, or to over-estimate it by over-heated enthusiasm. His judgment, however, was often very sound in such matters, and at all times there was an honest independence in the expression of his opinions, so that he acquired and enjoyed through life the friendship of some of the most scientific men of the day. In respect to his officers, Major Dawson, who was for some time intimately associated with him in the Scotch Trigonometrical Survey, observes—"That in the winter months he was pleased to have his officers with him, and was always most hospitable and kind to them; and that the trigonometrical survey under him, though certainly a wild and most arduous service, was nevertheless, for a young man, a life pleasant enough." And the same witness has thus spoken of his conduct towards the men:—"He would lend his own hand to the raising of stones and building objects for observation, or to make houses to shelter the soldiers in camp; he would occasionally join with the men in a game of quoits, or in putting the stone or crowbar, and was a warm promoter of their feast at the close of each trigonometrical season." It cannot be a matter of surprise that, under such a heart-warming system, privations and fatigues seemed as nothing;

and it is only to be regretted that some of his officers should have had reason to complain that he subsequently appeared to listen more to the dictates of utilitarianism than to those of feeling, in parting, as they thought, too coldly and readily, from men who had so long and so well served under him; but let us remember that he had then ceased to be the independent head of the Survey. With ordinary men, and in common things, he was rather eccentric, like the well-known character in Goldsmith's "Citizen of the World," never openly giving alms to the common beggar, and generally muttering something about the effects of idleness, whilst in secret he was warmly and liberally charitable. Here, however, this imperfect sketch of *the man* must cease, as it would be vain to attempt to pourtray his person more fully than has been done, or to bring home to those who knew him not the elasticity of his step, the rapidity of his movements in the streets, the slight peculiarities of dress which he so long retained.

The grandfather of General Colby was Mr. Colby, of Rhosygilwen, Newcastle Emlyn, South Wales, a gentleman of considerable landed property. His father, Thomas Colby, was an only son, and an officer of Royal Marines. For many years he appears to have been attached to the Chatham Division of Marines, and at that station most, if not all, of his children were born, the births of four being recorded in the registry of St. Margaret's *next* Rochester; a curious circumstance, as his family had already been connected with that locality through Sir Thomas

Colby, Knt., who, in 1724, was one of the representatives in Parliament of the city of Rochester, and contributed 200*l.* towards the repair of the Poor-house of this very parish, St. Margaret's. After this time Captain Colby again went to sea, and was severely wounded at the glorious battle of the 1st of June, 1794; when the "Queen," the ship to which he belonged, commanded by Sir Allen Gardner, assisted in breaking the enemy's array, and leading along the line and receiving successive broadsides, finally engaged the "Jemmapes" in a desperate conflict, which, though successful, left her too crippled to be able to take possession of her vanquished opponent. Captain Colby then attained the rank of Major in the Army. The grand-uncle of General Colby was Captain Colby, of the Royal Navy, who lost an eye in the service; he was also a gentleman of considerable property, and his estate, including the beautiful demesne of Fynone, is now in possession of John Colby, his lineal descendant, and nephew of General Colby, whose sister married her cousin, Mr. Colby, of Fynone. On the mother's side, General Colby was descended from Captain Hadden, who served at the celebrated siege of Belleisle.

It will be remembered that in 1761, or some few years after the defeat of the French fleet by Admiral Hawke, off this island, which lies at the north end of the Bay of Biscay, it was determined to make an attack on the island itself; and that, in consequence, the British fleet, commanded by Commodore Keppel, and having on board a considerable land force (8,000

men), under General Hodgson, approached it on the 7th of April. The island of Belleisle originally belonged to the Comptes de Cornouailles, a small district of Bretagne, by whom it was bestowed on the Abbey of Quimperlé; but the monks, finding it very troublesome to preserve their property from depredation and pillage, whether in war by soldiers or in peace by pirates, petitioned Charles IX. to permit them to exchange it for other property with the Compte de Retz, then Governor of Bretagne; and on the completion of this exchange the Count was raised (1573) to the dignity of Marquis of Belleisle. In 1718, during the reign of Louis XV., and regency of the Duke of Orleans, the island became, by exchange, the property of the Crown. It is a little to the north-west of the mouth of the Loire, nearly parallel to, and about seventeen miles distant from, the general shore line of Bretagne, though the peninsula of Quiberon approaches within seven miles of it. The length is about twelve miles, and greatest breadth six; and the island stretches from north-west to south-east: it is surrounded by rocks, and the side facing Bretagne is nearly inaccessible, the sea breaking with violence against its cliffs. About midway between Point Loemaria, on the south-east point, and the Conigues Roches, close to the south-west point of the island, stands Palais, the principal town on the north-east side, or looking towards Bretagne. This town is divided into two by a canal or inlet which receives the tidal stream, and is crossed by a bridge of communication. It is fortified; the most inhabited

portion, which lies on the one side of the canal, being principally covered by a horn-work, which is commanded by the citadel on the opposite side.

On the 8th of April the English attempted to and in a sandy bay, near Point Loemaria, but were repulsed with considerable loss, the enemy being in possession of a small fort near the landing-place, land having also entrenched themselves on a steep hill, the *base of which* they had *scarped* so as to render it somewhat like the newly proposed earth forts of Mr. Fergusson. For some time the weather prevented a renewal of the attack, but at length the whole English force was landed, and the enemy driven within the walls of the town; this successful attempt having been commenced by a small body of men under Brigadier-General Lambert, who scaled the rocks at a part where their apparent inaccessibility had rendered the defenders less vigilant, and at a moment when the attention of the enemy was occupied by a continued cannonading of the hill forts, and by two feints or false attacks. The garrison was subsequently driven from the town into the citadel, which finally capitulating on honourable terms, the island remained in possession of the British until the peace of 1763, when it was restored to France. These particulars have been mentioned, as a curious tradition, preserved in the Colby family, relates that Captain Hadden was accompanied, on this arduous occasion, by his son, a child of eight years of age, who with the agility of boyhood first climbed either the rock or the wall of the town, and thus, being followed by his father,

pointed out to the soldiers the way to victory. This boy soldier was subsequently Colonel Hadden of the 11th Regiment, and Paymaster of the Forces in Portugal. General Hadden of the Royal Artillery was another son of the Captain: he first served in North America under General Burgoyne, in 1778, and remained in that country until captured at York Town, 1781. In 1793, when a Captain, he became Secretary to the Duke of Richmond, Master-General of the Ordnance, and was afterwards on the staff in Portugal as Adjutant-General under Lieutenant-General Sir Charles Stuart. On returning to England he again became Secretary to the Master-General, and was finally appointed Surveyor-General of the Ordnance. On the 29th of October, 1817, he died, and in the "Morning Chronicle" of Nov. 5, of that year, a biographical notice of him concludes with a warm eulogium on his honourable character as a brave officer and a good man, ending thus:— "Of him, as it was formerly of a virtuous patriot, it may be justly said, he lived honest and died poor."

Cordelia Hadden, the sister of these distinguished officers, was mother of General Colby, who appears to have been her eldest child. He was born on the 1st of September, 1784, at Rochester, and baptized at St. Margaret's, on the 29th. His years of infancy were, like those of his brothers and sisters, doubtless passed either at Rochester or Chatham; but when his father again went to sea, he was confided to the care of his father's sisters, who lived at the family seat, Rhosygilwen, and by them brought up until sent to school at Northfleet, in Kent, under

Dr. Crakelt, an able master. The General often pointed out the grey tower of Northfleet church, and spoke with much feeling of his connection with its school. From Northfleet he was transferred to the Royal Military Academy at Woolwich, and obtained his first commission as Second Lieutenant of Engineers on the 21st December, 1801.

On the 12th of January, 1802, Captain Mudge, R.A., then Superintendent of the Survey, applied to the Earl of Chatham, requesting that Lieutenant Colby might be attached to that work, and his appointment took place the same day. Captain Mudge's letter, referring to Lieutenant Colby, as a young gentleman who has just got his commission, proceeds thus—"I find him, *on examination*, well grounded in the rudiments of mathematics, and in other respects perfectly calculated to be employed in this business. I beg to point out to your Lordship the expediency of Lieutenant Colby being attached to me with some degree of permanency, and to request you will assign him to my orders on that principle." It is certainly possible that the name of Lieutenant Colby may have been brought before General Mudge by his uncle, General Hadden, then Surveyor-General of the Ordnance, through the Master-General's Secretary, General Neville, who was a very near relative of Captain Mudge, but there cannot be a doubt that the selection was made from the motive assigned in the above letter; and that it was wise and just, and never regretted by General Mudge, may be gathered from his subsequent letter

of September 9th, 1813, in which he thus feelingly expresses himself:—"This brings to my mind how happy I am to account myself, that Providence has placed to my hand so able and firm a friend as you are. You have served without fee and reward; but find the greatest satisfaction for your actions in not having served in vain."

Under the authority of the Duke of Richmond, Master-General of the Ordnance, a corps of draftsmen (or surveyors and draftsmen) had been formed, and, as will be shown hereafter, employed to complete the topographical part of the Survey, by filling in the details required for a map. The establishment of this corps was a wise measure, and a necessary step towards the attainment of that harmony and perfection which ought to characterise a great national work. Mr. James Gardner, who was for many years chief draftsman, not only superintended the drawing and publication of the first maps, especially that of Kent, but also shared in the labours of much of the triangulation. To General Morse, then Chief Engineer, was due the very judicious idea of rendering this corps useful in instructing the young Engineer officers in sketching and surveying, and thus supplying one of the practical elements then wanting in the course of study. At his request, General Mudge allowed Mr. Stanley and Mr. Dawson, two of the most able surveyors and draftsmen of the corps, to undertake this task. In 1803, Mr. Dawson was engaged in the survey of Cornwall, and stationed at Liskeard, having then under him his three first

pupils, Lieutenant Williams, Boothby, and Boteler. Whilst there, Lieutenant Colby visited him on a tour of inspection, and when trying an old pair of pistols, and about to discharge one of them as he held the other by the barrel with his left hand, the latter exploded and burst, shattering his left hand, whilst one of the fragments made a fearful indent in his skull, the mark of which on his forehead was never obliterated. Almost dying, Lieutenant Colby was carried to the house of Mr. Dawson, when the local surgeons at once amputated the hand; and it was also proposed to resort to the hazardous operation of trepanning, but this design was abandoned. A constitution of unusual strength at length enabled him to triumph over the effects of this appalling accident, and he was mercifully restored once more to health; but it is impossible not to recognise in the injury inflicted on his skull, a sufficient cause both for subsequent bodily ailments, and for a reluctance to enter on long-continued mental exertion. At this point it seems desirable to pause, and to take a brief retrospect of the Ordnance Survey before General Colby succeeded Major-General Mudge as its superintendent.

Major-General William Roy, R.A., F.R.S., A.S., remarks that "Accurate surveys of a country are invariably admitted to be works of great public utility, by affording the surest foundation for almost every kind of internal improvement in time of peace, and the best means of forming judicious plans of defence against the invasions of an enemy in time of

war." And hence it is that the difficulties experienced in war from a want of accurate maps, and a consequent defective knowledge of the country to be included within a chain of military operations, has often led to the commencement of such works. The Scotch Rebellion of 1745, which was finally suppressed by His Royal Highness the Duke of Cumberland at the Battle of Culloden, pointed out the propriety of exploring and mapping the wild Highland districts, with a view to the establishment of military posts and roads of communication. In 1747 a body of infantry was encamped at Fort Augustus for this purpose under Major-General Lord Blakeney; and the plan of a Survey suggested by Lieutenant-General Watson, then Deputy Quarter-Master General in North Britain, was undertaken by General Roy, R.A., then Assistant Quarter-Master General, and the work was at length extended from the Highlands over the whole mainland of Scotland. This work was never published, and having been carried on with inferior instruments, was merely considered by General Roy "a magnificent military sketch." The war of 1755 put a stop to these works of peace; but at the peace of 1763 the subject of a General Survey of Great Britain, which would have included the work already done in Scotland, again engaged the attention of Government, and was again thrown into the shade by the troubles which preceded, and ended in, the American War. The peace of 1783 again restored that tranquillity which is equally necessary for the consider-

ation as for the execution of such works: and at this critical period (October, 1783) a memoir of M. Cassini de Thury, on the great advantages which would be derived by astronomy from the connexion through trigonometrical measurements of the two great observatories of Greenwich and Paris, and the consequent determination of the exact differences between their latitudes and longitudes, was submitted to the British Government by Count d'Adhemar, the French ambassador. The French had already carried a series of triangles from Paris to Calais, and it was only necessary that the English should complete the work by carrying a similar series from Greenwich to Dover. Mr. Fox, by the King's command, transmitted this memoir to Sir Joseph Banks, President of the Royal Society, and at his request General Roy charged himself with the undertaking, his Majesty George III. having expressed his warm approbation of the scheme, and supplied the funds necessary for the operation. The site of the initial base of this work, which must be considered the germ of all future scientific surveys of the United Kingdom, was fixed at Hounslow Heath; and, in this case also, soldiers—a party of the 12th Regiment—were employed to clear the ground, to protect the instruments, and to assist in the operations generally. Several modes of measuring this base were proposed and tried: the first was a steel chain, 100 feet long, constructed by Mr. Ramsden, on the principle of a watch chain, each link being one foot long, and constructed of three

principal parts, namely, a long and two short plates with circular holes at the ends of each, by which they were connected together by steel pins, adjusted to and passing through the holes. The second method was by deal rods, in imitation of similar measurements on the Continent; and three such rods were made of Riga red pine, being each twenty feet three inches long, reckoning from the extremities of their bell-metal tippings, two inches deep, and one-and-a-quarter broad, and which, being trussed both vertically and laterally, were sensibly inflexible. The third method was by glass rods, a suggestion of Lieutenant-Colonel Calderwood, of the Horse Guards, F.R.S.: three such rods, or rather tubes, were made, each twenty feet long, and inclosed in a wooden case eight inches deep, to the centre of which the tube was firmly fixed, the ends being left free to move in a longitudinal direction. The effect of trussing was produced on the cases by making them wider at the centre than at the ends, so that the sides were curved or arched.

It would appear from General Roy's statement, that the construction of the steel chain by Ramsden was undertaken experimentally, and rather with a view to obtain a useful instrument for future measurements, than for the determination, by it alone, of the length of this primary base. The deal rods, on the contrary, seem to have been relied upon, as that system of measurement had been before adopted on the Continent; but it was soon found that the variation in length consequent on

hygrometric changes in the atmosphere was very considerable. In an experiment, after a week of rain, the rods were found to have gained in length one-fifteenth of an inch, which would have made a difference of seven feet and a-half in the whole length of the base: in another, 300 feet were measured in one day, and the rods being left during the night on the grass exposed to a heavy dew, the measurement was repeated the next morning, when the length of the 300 feet line exceeded that of the previous day by nearly half an inch, which would have amounted to a difference of 45½ inches on the whole base. The great uncertainty consequent on such great and frequently very sudden changes led to the suggestion of the glass rods, with which the base was ultimately measured; though at the same time General Roy did not omit the opportunity of making a direct comparison between them and the steel chain, by measuring the same 1000 feet with both, and the result was very satisfactory, as, after making the proper reductions for temperature, the difference between the two measurements was only ·021 of an inch, equivalent to a difference of little more than half an inch on the whole base. Though the limits of a memoir of this description preclude the possibility of describing in detail these most interesting instruments, or explaining even the various modes of using them, and especially of determining the contact between successive rods, such as coincidence of lines, actual contact of the metal-tipped ends of the deal rods, &c., it is right to notice briefly the

ingenious method adopted in the glass rods: corks were introduced into the ends of the rods, which received and held fast a tube of brass, closed at the inner end, and open outwards; to the brass plate, or end of one of these tubes, was attached by a steel pin a brass neck, which exactly fitted the tube, and was terminated by a brass button which rested against the end itself of the glass rod, whilst in the other tube the connecting pin is free, and acts by a collar on a spiral spring, so that when the rods were brought together, the brass neck and button of one remained fixed, whilst the brass neck of the other tube readily slided inwards against the spring, until the cross lines on an ivory scale attached to it exactly corresponded with a fine line on the inner surface of the glass tube. This method of effecting contact is in itself very simple, and might, with the necessary modifications, be advantageously adopted under various circumstances, and especially with deal rods; and it may be added that the military engineer, when called upon to execute surveys in distant countries, will generally find that wooden rods must be resorted to, nor need he have any apprehension of the results if he only takes care to counteract their defects by either coating them with proper varnishes, or by filling their pores with any of those substances which will form an insoluble compound with vegetable matter. Some experiments for this purpose with Kyanised wood are required: as it would at all times be easy to supply our foreign stations with such materials, and with

sappers at hand, there could be no difficulty in constructing rods. The length of the Hounslow Base, as measured by General Roy, was, when reduced to the level of the sea, 27,404$\frac{3}{4}$ feet, or about 5$\frac{1}{5}$ miles; and the operation of measuring was attentively watched by the President of the Royal Society, and many of the leading scientific men of the day, and honoured on one occasion by the presence of his Majesty George III. The only officer of the Ordnance corps who was associated with General Roy in this work, and he as a volunteer, was Lieutenant-Colonel Pringle, Royal Engineers. The works thus commenced by the measurement of a base, though designed more immediately for ascertaining the relative situations of the observatories of Greenwich and Paris, had always been considered to have connected with it a still more important object, namely, that of laying the foundation of a general survey of the British Islands. For the first of these objects, a chain of triangles, the angles of which were measured by a circular instrument, or theodolite, 3 feet in diameter, constructed by Ramsden, was carried from the Hounslow Base to Dover, being connected with the Greenwich Observatory at one end, and at the other with a base of verification measured on Romney Marsh. The measurement of this second base was entrusted by General Roy to Lieutenant Fiddes, Royal Engineers, and Lieutenant Bryce, Royal Artillery, (immediately afterwards transferred to the Royal Engineers, and subsequently, as Sir A. Bryce, Inspector-General of Fortifications) and it

was executed with the steel chain of Ramsden, (the efficiency of which had been, as before stated, tested by direct comparison with the glass rods) as being better fitted for use in such ground. The length of the Romney Marsh Base, after reduction, was found to be 28532·92 feet, or rather less than 5½ miles, and differing only a few inches from its length as determined by triangulation from the Hounslow Base. The English triangulation was then connected with the French by observations from both sides of the Channel, and thus the data were obtained for deciding the relative positions of the two great national observatories; but on this occasion it is manifestly impossible to enter into any discussion either of its merits or of the results obtained. In addition to the great triangles, a great number of secondary triangles were observed, which became a sure foundation for the topographical survey of Middlesex, Kent, &c. In September, 1788, General Roy completed this great work, and returned to London, in very indifferent health; in 1789 his illness so increased that he was obliged to pass the winter of that year at Lisbon; in April, 1790, he returned to England, and died before the printing of his paper in the "Philosophical Transactions" had been completed, though he lived sufficiently long to correct all but the *three last sheets* of that most detailed and able account both of the instruments he used and of the nature, objects, and result of the operations he so successfully carried out. His work alone can here be cited; and it is therefore with re-

gret that the name of General Roy must be now passed by, without any attempt to do justice to his memory further than this brief record of the labours of the earliest British geodesist may have contributed to that object. Associated with General Roy in all his operations was Mr. Isaac Dalby, of whom General Roy had the highest opinion, and this eminent mathematician, who became afterwards Professor of Mathematics to the Military College, was, as it were, a connecting link between the preceding and the successive stages of this great work. Nor ought the name of the Duke of Richmond to be here passed over without some testimony to his memory and merits. General Roy particularly acknowledged the attention the Duke always paid to his representations; and it is from him that the great work of a national survey obtained its earliest and most decided support. Taking, then, into consideration the encouragement he conferred on this peculiar branch of the Ordnance service—asserting, by so doing, the claims of ordnance officers to be looked upon as scientific men—the patience with which he investigated the now popular subject of national defences, and the personal attention he bestowed on all the military departments of the Ordnance, including the Royal Military Academy, it may be justly said that the Duke of Richmond stands in the first rank of Masters-General of the Ordnance.

After General Roy's death the subject of a survey seemed, for a time, to be overlooked; but the Duke

of Richmond being informed that Mr. Ramsden had constructed a second three-feet theodolite, and two 100-feet chains, of great excellency, recommended to the Government that they should be purchased, and the work renewed, and this recommendation was successful. The first operation was a remeasurement with the new chains of the base on Hounslow Heath, and the result of this second measurement commencing August 15th, and ending September 26th, 1791, differed only from that of the measurement with glass rods $2\frac{3}{4}$ inches in excess. The new chains differed from the original steel chain made for the Royal Society, and before described, in this, that instead of consisting of 100 links of 1 foot, they were composed of 40 links only, each link being a parallelopipedon, $2\frac{1}{2}$ feet long, and half an inch square—a construction of great strength, and less liable to be affected by small irregularities in the supporting troughs or coffers, than a chain consisting of short links. At this stage of the proceeding, that simple, but most essential requisite, a safe observatory tent, was devised and constructed at the Tower: it was octagonal, and consisted primarily of an internal skeleton of eight iron pillars, bound together by oak braces, and supporting a roof consisting of eight rafters united together at the top, and clamped at the bottom to the iron pillars. The sides and roof were composed of frames covered with painted canvas, and the whole covered with a strong tent. This construction was afterwards slightly

modified, and then continued in use till the period of the Irish triangulation, when it was still further modified and improved. The spring waggon, which has always proved so effectual in the transport of the great instrument, and has tended so materially to preserve it from injury, was now invented and constructed. The stations having been selected by Captain Mudge and Mr. Dalby, the triangulation was extended, in the years 1792-93-94, southward to the Isle of Wight, and connected with the previous triangulation of Kent, so that the groundwork was laid for the survey of a most important section of the country, and data obtained for important philosophical deductions. The operations closed in 1794, with the measurement of a base of verification on Salisbury Plain. This base was measured with the steel chains, and was found to be 36574·4 feet long, the length, as obtained by triangulation from the Hounslow Heath Base, being 36574·3, exhibiting, therefore, a difference of little more than an inch in length of nearly seven miles. The direction of the meridian was determined at Dunnose and at Beachey; but it is unnecessary to enter on this occasion into the calculations of the length of a degree of a great circle perpendicular to the meridian, in the latitude of 50° 41′, which were founded on these observations. The operations of these years were conducted by Lieutenant-Colonel Edward Williams, and Captain William Mudge, Royal Artillery, and Mr. Isaac Dalby, and the results published in the "Philoso-

phical Transactions," in 1795. The same gentlemen continued to conduct the work, and in 1797 was published an account of the operations of 1795 and 1796. In these years the triangulation was continued westward, so as to embrace the whole southern and western coast, and means adopted to fill in the great triangulation by a minor triangulation, the angles of which were observed by a smaller theodolite, eighteen inches in diameter, constructed by Ramsden, on the same principles as the great three-feet theodolites he had before made. This latter instrument was therefore taken into Kent to complete the materials for the survey of that county, by Mr. Dalby, and Mr. Gardner, Chief Draughtsman in the Tower, who then commenced his connection with a work in which he long continued a most valuable assistant, whilst a series of triangles was observed with the great instrument, extending from the Isle of Thanet, in Kent, through the counties of Dorset, Devon, and Cornwall, to the Land's End, and even connecting the Scilly Isles with the mainland. The Marquis of Cornwallis was now Master-General of the Ordnance, and the work appears to have assumed the distinct character of a national survey. The name of Lieutenant-Colonel Williams does not appear in connection with it after the publication in "The Philosophical Transactions," in 1797, of the results of these two years' operations. In this paper Dr. Maskelyne gives the demonstration of that practical rule for

reducing the observed angles to angles of the chords, which was so long used in the British survey. In 1800, Captain William Mudge, then chief director of the work, communicated, by order of the Duke of Richmond, an account of the triangulation and survey in the years 1797-98-99. In this paper it appears that the Ordnance map of Kent had then been published, that the survey of Essex, portions of Suffolk and Hertfordshire, Sussex, Hampshire, and the Isle of Wight, were, under the direction of Mr. Gardner, in a forward state, and that the Master-General had directed the survey of Devonshire and such portions of Somersetshire and Cornwall as were necessary to square the work to be undertaken. Mr. Isaac Dalby, worn out with the fatigues of this arduous service, now retired, and was succeeded by Mr. Simon Woolcot. The Royal Society having lent to the Ordnance the great circular instrument, or theodolite, which had been used by General Roy, it was determined to use one of the great instruments in completing the triangulation necessary for the surveys thus ordered by the Master-General; and the other in carrying through the country the meridional line already commenced. In 1797, the operations were principally confined to the determination of the direction of the meridian by observations of the Pole Star, at Black Down, in Dorsetshire, Butterton, and St. Agnes' Beacon; and horizontal angles at a number of stations required to connect them with the meridian stations. The operations of

1798-9 included a considerable number of observations made for topographical purposes, and were therefore chiefly conducted by the chief draughtsman and surveyors of the Tower, under whom the actual survey was carried on; and also the measurement, in 1798, of a base on King's Sedgemoor, Somersetshire, in which a chain of 50 feet, made by Ramsden, was combined with the longer chains, and found very useful in facilitating a measurement over ground intersected by numerous ditches. The length of this base was 27,680 feet: but from the soft and shaky character of the ground, Captain Mudge considered it subject to an error of not less than six or more than nine inches, and it was found that the length of the base, as determined by triangulation from that of Salisbury Plain, differed from the measured length *by nearly one foot*. The account of all these operations was accompanied by a great number of latitudes and longitudes of stations, deduced geodesically from the calculated distances and meridional bearings. Hitherto the survey had done little towards the great astronomical question of the figure of the earth, although this object had always been present to the minds of its successive directors, and a new instrument, a zenith sector, had been several years before ordered from Mr. Ramsden by the Duke of Richmond, for the express purpose of being used in the celestial observations required in such an inquiry. This instrument was at length completed about the end of 1801, by Mr.

Berge, Mr. Ramsden dying just before he had put the last touch to it. It was the intention of Major Mudge to apply the extension of the survey triangulation northwards to the determination of an arc of the meridian, extending from Dunnose to the mouth of the Tees; and in 1802 the triangulation had been carried so far as to enable him to comprise within his celestial observations an arc of 2° 50′ 23″·38, extending from Dunnose in the Isle of Wight, to Clifton in Yorkshire; the sector having been observed at both these stations, and at Arbury Hill between them. This remarkable instrument was provided with a telescope 8 feet long, supported at its summit by means of a conical axis, on the Y's of a strong frame, and with a graduated arch 15° in extent, struck by the telescope as a radius. It admitted, therefore, of observing stars 7° 30′ on either side of the zenith. The instrument admitted of reversal in the plane of the meridian, and great ingenuity was displayed in all the arrangements for adjusting the plumb-line, for relieving the axis from pressure, for securing stability, and for facilitating the operations of observing, reading, &c.; and it was therefore naturally expected that with an instrument provided with an arch of so large a circle, the results of observation would be very superior, and most important data be obtained for comparison with the measurements of other countries; but it is remarkable that the results proved at variance with the deductions from other measurements, as the length

of a degree increased in approaching the equator in the following manner:—

	Latitude.	Length of degree in fathoms.
Middle point between Arbury Hill and Clifton	52 50′ 30″	60,766
Middle point between Dunnose and Clifton.	52 2 20	60,820
Middle point between Arbury Hill and Dunnose	51 35 18	60,864
Middle point between Dunnose and Greenwich	51 2 54	60,884

General Mudge did not conclude from these unexpected results that the earth was an irregular solid of revolution, and still less did he deduce from them an argument against the Newtonian theory of its figure; on the contrary, he explained them as the effects of deflections of the plumb-line of the sector, consequent on an unequal attraction due to the irregular distribution of the matter in the vicinity of the sector stations. It cannot indeed be doubted that all instruments of which the vertical adjustment depends on a plumb-line or any other contrivance, subject to be influenced by the force of gravitation, must, more or less, be exposed to this source of error, though at the same time it appears possible by a judicious combination of observations—as, for example, by observing at subsidiary stations to the north or south of the suspected station, and at short

accurately measured distances from it—to detect if not to avoid the error, and to determine its amount and direction. All geodesists did not, however, concur in opinion with General Mudge, and in 1812 a paper was published in the "Philosophical Transactions," by Don J. Rodriguez, in which that writer endeavours to show that the possible errors of the sector, as exhibited in the various readings of the same zenith distances, are sufficient to explain the observed anomalies; and the mode in which he conducts his investigation is curious. He first assumes an ellipsoid for the earth's figure, depending on the compression or ellipticity deduced from the various measurements of degrees in northern and southern latitudes, independent of the English, and then, with the calculated distances and observed azimuths, published in the account of the English survey, determines by calculation the length of the meridional arc in feet or fathoms, and deduces from that length and the elliptic elements the length in degrees, minutes, and seconds. Comparing this length as deduced from calculation with that obtained by the sector observations, he maintains that the difference is not beyond the limits of error of the instrument. Don Rodriguez, in conducting this comparison, adopts successively three different compressions, so as to get rid of any probable error in their determination, namely, $\frac{1}{300}$, $\frac{1}{320}$, $\frac{1}{310}$; and to prove the applicability of his method, makes a similar comparison between the observed and the calculated lengths of Svanberg's Arc in Lapland, and Lambton's Arc in the East

Indies, in both of which calculation and observation were found to be in perfect accordance. The last publication of the proceedings of the Survey, with which General Mudge was connected, was dated one year before the paper of Don Rodriguez; and it does not, therefore, appear that his remarks were ever replied to by General Mudge, though it must be admitted that they merited consideration, and seemed to render necessary fresh observations of zenith distances at the great sector stations, in order to confirm their accuracy and to support their testimony. When it is remembered that Don Rodriguez adopts an ellipsoid which had been determined from a comparison of the northern and southern degrees, it cannot be considered remarkable that, with that ellipsoid, he should again arrive, by calculation backwards, as it were, at those degrees; and though the difference between the observed English arc and the arc as obtained by calculation on Don Rodriguez's system does not much exceed the difference between some of the individual observations, it would be quite unreasonable to consider the whole of the extreme differences between the observations as due to error. In most cases the mean of a set of angles is more likely to be correct when by their variations they embrace every cause of error, than when they are all apparently identical in reading, though probably only so because they have been affected by the same errors acting in the same direction; still, however, when the demonstration of a remarkable physical fact seems to depend on the right interpretation of ob-

servations, no doubt ought to be allowed to remain of their accuracy and efficiency.

Up to this time the proceedings of the Ordnance Survey had been first recorded in the "Philosophical Transactions," the usual reports having been submitted from time to time to the Royal Society, by desire of the Master-General; and several reasons might be advanced in favour of this system, as it admitted of the publication of small portions of the work at moderate intervals of time, placed the results of observation and calculation in the hands of the most scientific men, and distributed them to all parts of the country, every Fellow of the Royal Society receiving a copy of the Transactions; and, further, it maintained that connection between the conductors of a great scientific work and those persons who are necessarily the best judges of its excellence, which it is most desirable should never be abandoned. On the other hand, the publication of the proceedings of the Survey as a distinct work, is more consistent with the position and character of a great national establishment, though it may be feared that it has hitherto narrowed the sphere of its utility by restricting a knowledge of what has really been done to those few persons who have chosen to purchase an expensive work, or have taken the trouble to examine it at the libraries of the Royal Society or British Museum. It would appear, however, very easy to secure the advantages of both these systems of publication; and, in doing so, to restore at once the connection between the Survey and the Royal Society on the one side,

and that between the Survey and practical men c
science on the other, by a modification which woul
approximate the system more to that of the Unite
States' Survey. The system suggested is this:-
That purely scientific matter, such as the measur
ment of an arc of the meridian, the measurements
bases, the determination of the greater triangles, th
description of new instruments or of new modes
calculation, should be recorded, as formerly, in th
"Philosophical Transactions;" but that all matt
of a practical bearing—such as the latitudes an
longitudes of stations, whether primary or secondar
the calculated distances between the stations (an
especially between those of a permanent and easil
recognisable character, such as church steeples, ta
chimneys, windmills, &c.), and the elevations of ob
jects, classified according to their probable accurac
as depending upon the mode of determination, an
being subject to a possible error of six feet, or of thr
feet, and so on—should be published either annuall
or biennially in a cheap octavo form, so as to be sol
by the agents for the sale of the maps at a very lo
rate, and thus put into the hands of every one in
terested in such matters. This suggested metho
would, it is presumed, do away with that insulatio
of the Survey which renders it unpopular with pra
tical men, and by making its results known witho
delay to the civil engineer, the surveyor, or even
the landed proprietor, would enable any one of th
to apply them to his own purposes and in his ow
way; and, further, let it be added, that such a syst

would show that the conductors of the Ordnance Survey were not only desirous to co-operate with other practical men, but that they courted for their work the most rigorous examination and criticism.

The first account of the Trigonometrical Survey, published as a distinct work, appeared in 1811, and embraced the operations of the years extending from 1800 to 1809 inclusive; but previously the several reports in the "Philosophical Transactions" had been republished in a similar manner, and now formed, together with the last one, a work of three volumes, of which that of 1811 was the third. This last volume is stated to be by Lieut.-Col. William Mudge, R.A., F.R.S., and Captain Thomas Colby, Royal Engineers, so that the services of the latter had already been fully appreciated by his able chief in this great work. In 1801 a base line 26342·7 feet in length was measured in the North of Lincolnshire, on Misterton Carr, and General Mudge laid down as a principle that a new base ought to be measured at each distance of 100 miles in the direction of the arc of the meridian, so as to serve as a base of verification for the work preceding, and an initial base for the work following it; a principle, however, which must be necessarily modified by the nature of the triangulation, and specially by the magnitude of the triangles. The Misterton Carr base served therefore for the extension of the work northward, whilst that measured in 1806 on Rhuddlan Marsh, near St. Asaph, in North Wales, was equally necessary for

its extension westward, through the central portion of the kingdom. This base was 24514¼ feet in length; and when the measured length was compared with that obtained by calculation, both from the bases of Hounslow and Misterton Carr, the results were highly satisfactory, as the difference did not exceed 1 foot. In the same year observations of the zenith distances of several stars were made at Delamere Forest in Cheshire, and at Burleigh Moor near the mouth of the Tees, Yorkshire; and the direction of the meridian was determined by observations of the Polar Star at both stations. From the data thus obtained and the calculated distances of the triangulation, the meridional distances between the parallels of Dunnose and Burleigh Moor, and between the parallels of Dunnose and Delamere Forest were deduced, and compared with the amplitudes of the celestial arcs as observed. In the one case the meridional arc was 3° 57′ 13″, and in the other 2° 36′ 12″. The length of the degree at the middle point between Dunnose and Burleigh Moor is determined to be 60823·8, in the latitude 52° 35′ 45″; whereas, as observed by Colonel Mudge, the length of the degree by the observations and calculations of previous years had been determined to be 60820 fathoms, or only about 4 feet difference—though, according to the ellipsoidal theory, the length of a degree in latitude 52° 34′ should have been 60830 fathoms, that of a degree at 52° 2′ having been taken as 60820, a difference which shows that there is much to reflect upon in the determination of the

value of this arc. The rest of this volume contains a large mass of most useful materials in triangulation primary and secondary, in computed meridional distances, and in latitudes and longitudes. As Lieutenant Colby joined the survey at the early age of seventeen years and four months, the period noticed in this volume must be considered his novitiate, and he could therefore only have been expected to act in conjunction with, and under the immediate direction of, Major Mudge. He seems, however, to have rapidly advanced in utility and in the esteem and confidence of his superior officer. In June, 1802, a few months only after his connection with the survey had commenced, he was observing at Dunnose, and on the occasion of his dreadful accident in December, 1803, Major Mudge thus writes to General Morse, then Acting Chief Royal Engineer—"I deferred addressing you on the subject till my arrival at Liskeard, for I was apprehensive that, with a relation of the accident, I should have to report his death. It is, however, with a degree of satisfaction proportionate to my regard for this most excellent but unfortunate young man, that I have to state the confident expectations entertained of his recovery,"—terms in an official letter which mark no ordinary warmth of feeling. In 1804, he was observing the Polar Star for azimuths, at Beaumaris; in 1806, observing with the zenith sector, at Burleigh Moor and Delamere Forest; and in 1811, he was in South Wales actively engaged in selecting and fixing stations, so that he had then, under the

direction of General Mudge, taken part in every one of the great operations of the survey, the base on the Rhuddlan Marsh having also been measured within the period now under notice. The appointment of Lieutenant-Governor of the Royal Military Academy was conferred on General Mudge (then lieutenant-colonel) in July, 1809, and from that time the executive duties of the survey were principally performed by Captain Colby, though, from the want of a published account, it is not easy to trace accurately his movements. His military progress was as follows: first lieutenant, 6th May, 1802; second captain, 1st July, 1807; captain, 5th March, 1812.

In July, 1811, Lieutenant-Colonel Mudge addresses Captain Colby (from Brighton) at Brecon, and communicates to him doubts expressed by Captain Hurd, Hydrographer of the Admiralty, as to the longitudes and latitudes of some important coast points: "Ponder," he says, "the contents of his letter, and when you can speak decidedly on the question, let me hear from you. I think the latitudes and longitudes of the Smalls Lighthouse, and Gresholm Isle, as given in the account, are right; I have not a copy of the work by me, or I should perhaps be able to determine the matter myself. I think you told me, on one occasion, that Gresholm Isle was not rightly fixed by the triangles first given. It is of consequence that Captain Hurd should be either proved wrong, or that the errata he has discovered may be acknowledged to be such, and these errata put to rights;" an extract which proves

the important position then occupied by Captain Colby, and the early attention he had paid to the correctness of the survey work. At this time Lieutenant-Colonel Mudge appears, from his letters to Captain Colby, to have been much distressed by a delay on the part of the Master-General and the Board, in sanctioning the publication of the account of the survey by Mr. Faden, and it is not unlikely that the recollection of these difficulties subsequently operated on General Colby's mind in checking an inclination to renew the subject of publication.

Another source of anxiety was the inquiry of "the military commissioners," before whom Colonel Mudge was summoned in his double capacity of Lieutenant-Governor of the Royal Military Academy, and Superintendent of the Survey. In his letters of September 2nd and October 1st (1811), the general results of this examination are stated to have been favourable, as he observes, "I am certain they were impressed with an idea of the extreme accuracy of the work," though it would appear that he expected from the commissioners some strong animadversions "on the apparent magnitude of the sum" expended upon it. The total expense of the work, for the first twenty years, from 1790 to 1810, as stated by Colonel Mudge, was as follows :—

Triangulation ...	£21,000	for the whole twenty years.
Interior survey..	25,347	from 1800 to end of 1810.
Engraving	7,818	from 1801 to end of ditto.
Total	£54,165	

Or, if the average be taken upon the whole period, an annual expense of 2,208*l.*; and if the average be taken on the last ten years only, which is more correct, an annual expense of 4,416*l.*—a sum very different from that assigned by public rumour, an anonymous writer having published a statement that "the expenses of the survey had exceeded 10,000*l.* per annum!" In Colonel Mudge's letter of November 5th (1811), it is stated that an application had been made by the Quartermaster-General to have the plans drawn from the survey sent to the Horse Guards, to be there *copied* for the use of his department. This measure was advocated by the Duke of York, and it was afterwards arranged that the plans should be sent to the Horse Guards in parcels of four, five, and eight, in succession, until the whole had been copied, and that this arrangement should apply to the future maps as well as to those already finished. After the publication of the account of the survey, in 1811, it was determined to prolong the meridional line into Scotland, and the triangulation of the mountainous districts of that country opened out a new field for the display of those personal energies for which Captain Colby was so remarkable. On the 9th September, 1813, Colonel Mudge writes—"I have now to beg you will send me, upon a sheet of paper, a sketch of your triangles, with your meridional line laid down thereon, telling me when you give up the business; and you will now hear with great satisfaction the probability of my returning with you to the north next spring, to

finish our operations, for my health is much restored, and though I write by the hand of another, yet I am in many respects better than I have been for some years;" and he closed this letter with the passage of grateful eulogium on the services of his assistant and friend, which has already been quoted. The mind of Colonel Mudge was at this time much harassed by the attacks of various critics, some of whom gave their names, and others wrote anonymously. The paper of Don Rodriguez may be said to have led the way in this attack, although a candid reader of the present day will, it is believed, find nothing in that paper but a fair expression of doubt as to the sufficiency of the evidence afforded by the zenith sector observations for the determination of a great physical question. At the time, on the contrary, it seems to have been considered and treated as a personal and invidious attack either on the superintendent of the survey, or on the survey itself; and this mistaken feeling is strongly manifested in the letter which has been here quoted, whilst directing the attention of Captain Colby to a critical essay in the "Edinbugh Review," ascribed to Professor Playfair, on Colonel Lambton's reports on the Indian Survey. It is refreshing to observe the calm and candid tone in which Playfair examines the subject, in reference to the meridional arc measured in England. He first gives the various lengths of a degree determined by Lambton, as deduced from parts of the general arc of about three degrees—

	Fathoms.	Middle Lis		
Punnae and Putchapoliam	60473	9°	34′	44′
Punnae and Dodagoontah	60496	10	34	49
Punnae and Bomasundrum	60462	11	4	44
Punnae and Panghur .	60469	11	8	3
Mean of the two last .	60465·5	11	6	23
From a former measurement	60494	12	32	0

And then pointing out that the same anomal appear in these results as had been noticed in t measurements both of France and England, a especially in those published by Colonel Mudge, observes, that "such anomalies will probably alw occur where contiguous parts of the same arc compared with one another. The degree in parallel of 11° 6′ 23″ is less than that in parallel of 9° 34′, a degree and a half further to south. This is similar to what appears in the deg in England; and there is an instance of the sa species of retrogradation, when the parts of arc between Dunkirk and Formentaro are compa with one another. Some part of this irregular but *certainly a very small one*, may be ascribed error of observation; the greatest part must, think, be placed to account of the irregularity the direction of gravity, arising from the irregul ties at the surface or in the interior of the ear the attraction of mountains, for example, or local variations of density in the parts immediat

under the surface. We long ago remarked, in speaking of the Trigonometrical Survey of England, that it *would have been of great importance to have added to it a mineralogical survey*, as the results of the latter might have thrown some light on the anomalies of the former. The same thing is suggested by the objects now under consideration. It would be extremely desirable also to have a vertical section in the direction of the meridian and of the perpendicular, at those places where observations for the latitude are made. This might afford a satisfactory solution of many difficulties which at present are sufficiently perplexing, and seem to increase just in proportion to the extent and accuracy of the observations." This admirable suggestion was subsequently advocated warmly, both by Colonel Mudge and Captain Colby, and the result was the appointment of Dr. M'Culloch to act as mineralogical surveyor, in connection with the survey of Scotland. Major Lambton had found the length of a degree in latitude 11° 59′ 54″, equal to 60529 fathoms by one set of deductions, and by another 60449; and as the stations from which these results had been obtained were sufficiently remote from mountains to remove all suspicion of a disturbance from that cause, although the existence of *some disturbance* was undoubted, he attributed it to the effects of a bed of iron ore which had drawn the plummet northward at Dodagoontah, and southward at Bomasundrum, so as to give the celestial arc between Dodagoontah and Putchapoliam (to the south of both the other stations)

too little, and that between Putchapoliam and Bomasundrum too great—a case quite analogous to that of the English arc. "The anomalies," as Playfair goes on to observe, "which have occurred in t measures of degrees, and of which the appearances seem to increase in proportion as greater pains are taken to avoid inaccuracy, have naturally drawn the attention of mathematicians; and the question, what part of them is to be ascribed to error, and what to irregularity in the structure of the globe, has c of course, to be considered. That a small] t them only can be ascribed to the former cause, is rendered probable by the very circumstance just stated; that they are not diminished, nay, that they even seem to be increased, by the care taken to a error. It seems clear from that consideration the irregularities are in the object sought for, are only brought more in sight by more microsco observations, by the excellence of the instru , the accuracy of the computations, and the extent the lines measured." But though Playfair i the fact that in Colonel Mudge's arc t de s appear to increase on going from the north to south to local irregularities in the direction o gravity, and not to instrumental errors, he charac terises the paper of Don Rodriguez as being w with great knowledge of the subject, and full o sound mathematical reasoning, notwithstanding i takes the opposite view of ascribing the irregu ties in the arc to errors of observation. "Don Rodr guez," he observes, if we mistake not, "is one o

two Spanish gentlemen who accompanied MM. Biot and Arago, and assisted in the operations by which the meridian that had been traced through France was extended to the southernmost of the Balearic Isles. He seems perfectly acquainted with the methods of calculation, and all the most recent improvements which respect the problem of the figure of the earth. We do not think that he has proved that the irregularities in this measurement arise from errors of observation; and we are of opinion, though their amount may now be more exactly estimated than before, that with regard to their cause the question rests precisely where it did. But though we are not convinced by Don Rodriguez, we must do him the justice to say, that his argument is fairly conducted, and that he has displayed great knowledge of the subject, and perfect familiarity with the best methods hitherto employed in the solution of this difficult problem. We have, therefore, observed with regret that this ingenious foreigner has been attacked in some of the English journals with a violence and asperity which the subject did not call for, and which his paper certainly did not authorise."

This just and candid criticism did not quite satisfy Colonel Mudge, who appeared to think that the Edinburgh Reviewer was unwilling to allow any other hand than his own "to wield the tomahawk" of criticism; but it is impossible, at the present day, not to concur with Playfair in thinking that Dr. Olinthus Gregory, to whom his remarks applied, was

quite unjustified in such a system of defence, and rather injured than assisted Colonel Mudge, by adopting it; and that Playfair wrote with no ill-feeling towards the Survey or its managers, may be fairly deduced from his closing paragraph :—"It is with pleasure, therefore, that we see a meridian, which has been extended from the shores of the British Channel along the west side of England, viz., the meridian of Delamere, now produced into Scotland, where it falls on the east side of the island, and is about to be continued till it intersects the shores of the Murray Firth, on the Northern Ocean. The combined arcs in France and England will then extend nearly to twenty degrees; and in a few years we shall perhaps see the distance between the parallels of the Balearic and the Orkney Islands ascertained by actual mensuration. We believe that the important operation *could not easily be in better hands than those in which it is actually placed;* and, when it shall be completed, the British Army—in General Roy, R.A., and the officers who have succeeded him in the conduct of the English Survey, and in Major Lambton, whose works in the Peninsula of India we have been now treating of—will have the glory of doing more for the advancement of general science than has ever been performed by any other body of military men." A noble tribute of praise from such a man as Playfair, in comparison with which the ordinary articles of the public journals, whether written in defence or in attack, should have been regarded as mere dust in the balance.

Notwithstanding the little value attached by General Mudge to the remarks of Don Rodriguez, the subject was often present to his mind, and in May, 1814, he writes: "In reference to this matter, and still more in reference to the importance of satisfying the public mind, now very anxiously bent upon this point, I should have derived infinite satisfaction from the zenith sector being this year used instead of the circular instrument, and I am sure I cannot see why it should not be so used, for I should be in that case enabled the sooner to put up the zenith sector on Arbury Hill, which I have promised to do, and certainly will do, to vindicate the memory of Ramsden." At this time the triangulation had been pushed into Scotland, and so earnestly intent was General Mudge on the repetition of the zenith sector observations in England, that he does not appear to have approved, in the first instance, of the project of extending the arc of the meridian to Shetland, which most probably originated in Captain Colby. In the same letter he says, "Now, I beg of you most seriously to take into consideration that it is my wish, if you can accomplish it, to finish the sector work this year (1814). What use is there in your going to Shetland with the sector? I can see none. Certainly there is none, for the arc will be long enough if ended upon the remote part of Scotland, short of the isles, and by causing us so to do a finale would be given to the sector. Let us not prolong it unnecessarily, but give a speedy finale to the meridional operations; the public very anxiously look for it."

There cannot, indeed, be a doubt as to the g
interest which naturally attached itself to t
branch of the Survey, and especially to the inv
gation of the causes which had led to ap
anomalies in the results; though, at the sa t
it would perhaps have been a matter of reg to
have curtailed the fine arc of more than ten deg
between Dunnose and Balta, which was obtained by
continuing the work to, and making the last sector
observations at, the latter station. By carrying out
the design, however, General Mudge was disappointed
in his hope of repeating the observations at Arbury
Hill, as it was impossible, during his life, to apply
the sector to such a purpose. So far, however, as
the character of Ramsden's instrument entered i
the question, it has been most satisfactorily v
cated by observations made with the new sector,
instrument constructed under the direction of Professor Airey, Astronomer Royal, on totally different
principles, as may be judged from the following
comparison, in which the finally corrected r lts
(using all the observations and applying the
formula) of the old zenith sector are adopted:—

	Latitude.
Dunnose, by old sector observations	50° 37′ 7·05″
Ditto, by new sector ditto .	50 37 6·98
Cowhithe, by old sector ditto .	57 41 9·47
Ditto, by new sector ditto .	57 41 9·58
Balta, by old sector ditto .	60 45 1·59
Ditto, by new sector ditto .	60 45 1·68

Examples of agreement between the observations of totally different instruments, taken at a considerable interval of time, not perhaps to be equalled by those of any similar geodesical or astronomical operations; and, it may be added, that the fact of a deflection of the plumb-line at Dunnose, to the extent of about 3″, has been proved by observations near the station, taken somewhat in the manner pointed out in a preceding page of this memoir. The difficulties inherent to the determination of latitudes, as required for the estimation of the celestial amplitude corresponding to an arc on the earth's surface, had indeed been discussed by some of the most able observers, as few have escaped entirely from an apparent discordance, in some particular case, between the angular lengths of arcs determined geodesically and astronomically. An instructive example may be cited from the astronomical correspondence of Baron Zach, in reference to the survey in Tuscany, by the Rev. Father Inghirami, Professor of Astronomy and Director of the Observatories at Florence. This able and singularly candid man had provisionally founded his survey on a *very small* base, only 426 toises (931·7 yards), a little more than half a mile in length, measured by Baron Zach, and having most carefully conducted his triangulation and verified its results by several independent series of triangles, he attempted to determine geodesically the difference between the latitudes of the observatories of Pisa and Florence, when, to his surprise, he encountered the following discordant results. The latitudes of both

these observatories had been determined astronomically, but starting from that of Florence, the geodesical and astronomical latitudes stand thus in contrast with each other—

Geodesical by triangulation, from Florence, latitude	43°	43′	19·4″
Astronomical by 504 observations of Stars	43	43	11·77
Difference			7·63

Now this difference was enormous, and would have implied an error of more than 200 yards in the measured arc, if such had been the cause of the discrepancy between the results. The first idea of Inghirami was to attribute the error to the small length of Zach's base, and he at once undertook the measurement of a much longer base in the great plain between Leghorn and Pisa. This base was 9824 yards, or more than five and a half miles in length, and the measurement was effected in two different modes; namely, by direct measurement with deal rods and by triangulation—a system which will be hereafter explained.

The following is a comparative view of a portion of the base thus determined:—

			Feet.
By triangulation . .	10705·9	Florentine .	20499.8
By actual measuring with rods	10706·8	Braccii . . .	20501·7
	0·9		1·9

Or nearly two feet in rather less than four miles—a difference not greater than that found in separate measurements of some English bases, and far too small to affect sensibly the general results.

Inghirami then proceeded to test the accuracy of his first deductions from Baron Zach's small base, by closing the triangulation, depending on that base, upon this newly measured base, when he found the distance between the belfry of S. Pietro in Grado, and the corner of the old ducal palace of Stagno, stood thus—

	Feet.
By one chain of triangles	29454·3
By a second chain of triangles . . .	29449·7
By direct measurement	29449·9

This unexpected confirmation of his first results was not received by the worthy Father with the satisfaction which might have been expected, but, on the contrary, actuated by a totally different feeling from that which had influenced the English geodesists, he warmly expressed his regret that his work should have been thus placed in opposition to astronomical observations. "How," he exclaims, "shall I struggle against this most unexpected anomaly in the position of Pisa? It is a rock on which I must be wrecked, as no art can save me! I measured my new base with the hope that, connecting it with Pisa, on the one hand, and having the other base of reference at the other end of the chain, I might the better discover the cause of my error; but all has been in vain, as the new base tells precisely the same tale as

the old. It is impossible to say whether I was more surprised or more vexed at this result, as one totally different was both expected and required to place my operations in accordance with the previous observations." Such, says Baron Zach, were the painful feelings which agitated Inghirami, on discovering this apparently inexplicable difference, just as M. Mechain had been distressed and worried by a similar case in France, and it may be added General Mudge, by that of the English arc. The causes of the strange differences which had been thus experienced by Maskelyne, Mudge, Lambton, Mechain, Schiegg, Inghirami, and himself, should, as Zach considers, be sought for in one of the three following causes, namely—

1. Errors in the instruments, or errors of observation.

2. Deflection of the plumb-line, or disturbance of the levels by local terrestial attraction.

3. Irregularity of figure and of conformation of the earth.

As an example of the difficulty of accurately determining latitudes, even by the most excellent fixed instruments, Baron Zach cites the successive changes in latitude of Greenwich, viz., by Bradley, 51° 28 41·5″; Maskelyne, 40·7″; Bessel, by 2008 observations of Bradley, 39·56″; Pond, 38·5; to which may now be added Professor Airey's determination, 51 28′ 38·3″; "so that 2000 observations and sixty-four years' work have not sufficed to settle the true second of latitude of the Greenwich Observatory. So long,

indeed, as it is necessary to use plumb-lines or levels in the determination of altitudes—and on them depends the determination of latitudes—it cannot be expected that we shall attain to the same precision as can be readily secured in horizontal angles, or that we can obtain latitudes by ordinary or moveable instruments within two or three seconds." Baron Lindenau, of Gotha, expresses himself even more strongly: "The zenith observations," he observes, "of M. Bessel, at Königsberg, which in themselves constitute so striking an accordance, give, nevertheless, declinations of the stars, which are less by 3·2″ than those of Pond, Piazzi, and Oriani;" and he adds, what has happened to Inghirami, in his measurement in Tuscany, has similarly occurred in all great geodesical operations. In France it was necessary, in order to reconcile the results to a spheroid, the flattening of which was $\frac{1}{305}$, to suppose errors in the latitudes of Dunkirk, Evaux, Carcassone, and Montjouy, of 3·1″, 5·8″, 0·8″, 3·6″, and in England the results were still more discordant, as they represented an equatorial and not a polar flattening, and would have required a supposed error of 8″ in the latitude, to reduce them to order."

In respect to the two other causes, whilst Baron Zach admits the probability of local attractions and disturbances of the plumb-line, rather from the unequal distribution and density of the matter below the surface, than from the action of hills projecting above it, he seems more disposed to ascribe the discrepancies experienced to irregularity in the form of

the earth itself, and quotes the opinion of La Place to that effect. Baron Lindenau, on the other hand, rejects such explanations, and ascribes the difficulty of reconciling geodesical latitudes and longitudes with those determined astronomically, entirely to the defects of astronomical observations, partly resulting from the imperfections of instruments and partly from the defects of physical astronomy. It is not intended to enter here into a detailed discussion of this most interesting question, but it seemed only due to the reputation both of British artists and British observers that the true nature of the difficulties they had experienced, as well as their generality, should be made apparent. Two of the causes of such difficulties which have been cited, namely, first, the improbability of determining latitudes astronomically to the utmost precision by moveable instruments; and, secondly, the effects of local terrestrial attraction, cannot be reasonably rejected, as more or less influencing geodesical results; but it seems difficult to ascribe such great differences as those observed in England and Tuscany to irregularity in the figure of the earth alone, although it is highly probable that there is a certain amount of such irregularity. The more the physical condition of the earth is investigated, the more evident does it become that the matter immediately below its surface varies greatly from place to place in its density and properties, a fact which is strikingly exhibited in respect to the progression of temperature on descending into the interior of the

earth. Whilst, for example, under ordinary circumstances, the temperature increases by about 1° Fah. in 55 feet, it was found, in a boring at Neuffen, in Wurtemberg, to amount to 1° in about nineteen feet, an indication of great internal heat, which could only be accounted for from the proximity of the boring to large masses of basalt, which still retained a very high temperature. Can it be doubted that such masses of very dense matter, only recently fused under enormous pressure, would be a powerful attractive force, and exercise a powerful disturbing action; and, further, that such masses may be subject even to change of position, and therefore may so vary in the amount of their action as to produce different results at different times? These considerations will assist the reader in appreciating the accuracy of observations and the difficulty in guarding them from the effects of disturbing causes. General Colby was concerned either as principal or assistant in all the sector observations on which the comparison between the terrestrial and celestial arcs had been or will be founded. With General Mudge he observed at Dunnose, Clifton Beacon, Arbury Hill, Delamere Forest, and Burleigh Moor, and, aided by Mr. Gardner, he conducted those of Kellie Law, Cowhithe, and Balta; and the zenith distances, taken at the same stations, with Airey's sector, were observed by Sergeant James Steel, of the Royal Sappers; so that the system of employing trained soldiers on this great work, introduced by General Colby, attained, during

his time, its fullest development, and it may be cited, as a proof how entirely he was above the feeling of petty jealousy, that he thus directed his own personal observations, the observations of his most able days, to be tested by Sergeant (then Corporal) Steel. But though, in the abstract, this result was most satisfactory, it may be doubted whether General Colby contemplated, at first, so great an extension of his system, and whether, in fact, it has not now been carried beyond the limits of sound policy. The survey was considered by General Morse, as pointed out in a preceding paragraph, a fitting school for young officers, and it subsequently became, when extended to Ireland, a real and practical school for both officers and soldiers in every branch of surveying. Such a school it ought still to be, but when the officers are entirely abstracted from that class of observations with which it is most desirable that they should be familiar, it may be feared that they will never become either practical surveyors or practical astronomers; and though it is most gratifying to render the Sappers and Miners equal to the performance of every description of duty, the officers of Engineers should, at least, keep pace with them, and be prepared either to direct or to participate in their scientific labours. The survey, indeed, should be a field of operation for those officers who have distinguished themselves at the Royal Military Academy or at Chatham by their acquirements, theoretical and practical, in geodesical science, and it should afford to them the

means and opportunity of perfecting themselves in every description of observation as well as of calculation.

In the volume of sector observations just published, Captain Yolland does not enter on a comparison between the geodesical and astronomical amplitudes of the great or complete meridional arcs, as he justly observes, that "such comparison will be more properly dealt with in discussing the results of the triangulation, when the question of the standards of measure employed at different times on the Ordnance Survey, and the elements for the figure of the earth used in computing the geodesical amplitudes, will have to be taken into consideration:" and adds, that the geodesical amplitudes he publishes must be considered only as approximative, "as at present they all relate to feet, in terms of the ordnance ten-feet iron standard bar O, which there is no doubt is too short as compared with the standard used for the trigonometrical survey in England by Major-Generals Roy, Mudge, and Colby, and whose results have been employed by the Astronomer Royal, Professor Bessel, and others, in the determination of the figure of the earth." This comparison of the standards, or, in other words, the determination of the actual unit of measure, was constantly present to the mind of General Colby, when projecting and maturing his arrangements for the Irish survey; and its importance is so manifest, that it may be hoped the experiments there commenced will be completed, and the comparative

values of the several scales used both at home and abroad accurately determined. Several very interesting comparisons are, however, given of the amplitudes of short arcs, and though in several of these there is a considerable difference between the astronomical and geodesical determinations, the difference varies so much both in amount and direction, that it would be impossible to account for it by any general irregularity in the form of the earth. Captain Yolland treats the differences as entirely due to local attraction, or to deflections either of the plumb-line or of the level, and in such a case as that of the amplitude between Cowhithe and Gr Stirling, in which the geodesical is less than the astronomical amplitude by 9·48″, there cannot a doubt that the larger portion of the difference n be due to local attraction, though some hesitation may be expressed in ascribing minute differences of 0·6″ to that cause entirely, when very conside differences are observable in the latitudes of same station, as determined from different stars; example, in that of Ben Heynish, where the tremes are 56° 27′ 20·04″ and 56° 27′ 11·94″, e though the system of allowing to the several r a value proportionate to the number of obser of each star tends so materially to strike a corr balance. It may, however, be justly said of last volume of the Ordnance Survey, which is in the last record of the labours of General Colby, it contains very little which he had not ordered to b done before his separation from the work, that it ca

hibits great care and judgment in investigating, by the observations of collateral stations, the probability of local disturbances, and thereby assisting to free the terminal stations of the great meridional arcs from sensible errors. But Captain Yolland states "that General Colby, immediately after the construction of the new zenith sector, selected certain points for making observations from, so that in the determination of the figure of the earth by meridian measures, more than one arc of meridian should be available from the trigonometrical survey of the United Kingdom, for combining with the measures made in other countries;" and he thus added to the original meridional arcs one extending from Hensbarrow, in Cornwall, to Ben Hutisch, in Sutherlandshire, and another from the Hill of Forth, in Wexford, through the south end station of the Lough Foyle base to Monach in the Isle of Lewis, which has been subsequently extended southwards to the station near St. Agnes' Lighthouse, in the Scilly Islands, and northwards to North Rona Island, off the North-west coast of Scotland, with the sanction of Lieut.-Col. Hall, his successor as superintendent of the survey. When all these arcs have been combined together, it may well be expected that a more accurate knowledge of the actual figure of the earth, within this portion of the northern hemisphere, will be acquired than could have been reasonably expected, and many glimpses obtained of the position and magnitude of those masses of igneous rocks which have been agents in uplifting and fracturing the stony crust of the earth.

When the triangulation had been carried into Scotland, it required all the energies of Captain Colby to meet the demands upon him, as he had not only to conduct the observations in the field, but also to watch and regulate the proceedings of the interior survey. In 1813, Captain Colby, assisted by Mr. Gardner, visited two principal stations in Scotland, and two more were visited by Mr. Gardner; in 1814, Captain Colby observed from ten stations, and Mr. Gardner from four more, and when the preliminary labour of examining a country and fixing upon stations has been explained, the amount of activity and perseverance called forth by a "season on the hills" will be understood and appreciated. In 1815, Captain Colby appears to have been obliged to attend much to official business at the Ordnance Map Office in the Tower, and to the superintendence of the topographical survey in England and Wales, in consequence of which the actual observations with the great instrument in Scotland were, during that year, principally made by Mr. Gardner,—though, aided by that activity and energy which seemed to bestow upon him the power of multiplying himself, he did not neglect to watch over his favourite work, and hence in a letter of this year he thus writes,—"Our theodolite sustained no injury in the very violent storm which destroyed the tents, and put an early period to our summer's operations. But the weather, during the whole of the season, was so unusually unfavourable in the west of Scotland, that I was quite disappointed as to the quantity of work which from a comparison with other summers I had

expected to be able to perform. We commenced on Bengairn Hill, near Kirkcudbright, and concluded on the Black Carrick Hill, near Ayr; thus completing the connection between Cumberland, the Isle of Man, part of the coast of Ireland, and the south-west of Scotland, as far as Ayr. The survey is now advanced to that state in which the determination of the positions of the observatories of Edinburgh and Glasgow became the next object for consideration. I find that both are in sight of such stations as will
n well-shaped triangles with them, and at the
time that Ben-Lomond to the north and the
arick hill to the south, will each give two sides
an included angle to compute their distance
fr each other. If we may admit the principle of
two es and an included angle to ascertain the
verging of meridians, Ben Lomond being also
from the Island of Isla, a large extent may be
n red in that way perpendicular to the meridian."
that it may be safely said, that though his hand
not always regulated the movements of the in-
ent, his spirit had planned and directed the
rations on which it was engaged.

From a copy in his own handwriting of this remarkable letter, addressed, apparently, either to Prof. Playfair or Prof. Leslie, it is right to extract e passages which mark the high value which then set upon his opinion, as well as the lightened view he always took of scientific sub-ts. He had been consulted respecting the Edin-gh observatory, and he replies, "Having had a

good deal of conversation with Mr. Wm. Play
about the Edinburgh observatory, and seen
plans for the building, I was desirous to consult
as to what is the best means for raising a fun
defray the expenses of the building and the an
salary of the observer. Surely there is no cou
on earth to which astronomical science is of so n
consequence as it is to Great Britain; and the
gress which the mathematics have made, and
making, at Edinburgh, points it out as one of sev
fitting places in the island for the cultivatio
astronomy. Add to this, the Calton Hill pres
an admirable situation for the erection of a scien
observatory. It is near enough to the city t
under the continual superintendence of the pr
sors of the university and other learned men, an
the same time so far elevated above it as to pre
the smoke from interfering with the observati
The foundation being a rock, is also no small ad
tage. In short, so numerous and cogent
reasons which may be given in favour of the
nomical institution of Edinburgh, that I can
think the Government would withhold its aid if
were fairly set forth for their consideration.
annual sum required for its support would b
small in comparison of the good which it m
certainly be expected to produce, that the most r
political economist, if acquainted with the natur
the subject, must give his assent. No science
arts can remain in the same state for any lengt
time; they must either be improving or fallin

decay. The experience of the world has taught us that they fall much faster than they rise. Without due encouragement astronomical science may gradually decline; and it is of so much importance to the honour and the interest of our nation to support it, that I scarce think such a memorial as would emanate from your pen could prove altogether ineffectual." Since the time when Captain Colby thus forcibly expressed his opinions on this interesting subject, the multiplication of working observatories, public and private, at home and abroad, and the many important discoveries which have been the result of such continuous and wide-spread observations, have at once, as it were, responded to his appeal, and justified its wisdom.

In the earlier period of his connection with the Survey, Captain Colby had usually established his residence, when not in the field, as near as possible to that of General Mudge, but his immediate presence at head-quarters became desirable when the work of reducing the actual surveys to the scale required for engraving, which necessarily increased proportionately to the number of surveyors employed in the field, had so far augmented as to render constant supervision indispensable, and he had, therefore, taken possession of apartments at the Drawing Room, or Ordnance Map Office, at the Tower. Surveyors belonging to the corps of Surveyors and Draughtsmen were now employed in various parts of the country, by permission of the Chief Engineer (Inspector-General of Fortifications), who was the

official head of the corps, and they received, besides their military pay as warrant officers, 32*s*. 6*d*. per square mile for all the work they surveyed and plotted on a scale of two inches to the mile. These plots were reduced at the Map Office to plans on a scale of one inch to a mile, and traces from them prepared for the use of the engravers. It will be readily believed that the superintendence of all these operations, simultaneously proceeding at so many different places, some in the Map Office, some at various parts in the country, combined with the personal direction of the triangulation in Scotland, was enough to overpower the mental energies and the physical powers even of a Colby; and in 1816, therefore, at the recommendation of General Mudge, his son, Lieutenant Richard Mudge, R.E. (now Lieutenant-Colonel Mudge), was attached to the survey, and stationed in the country, as nearly as possible in the centre of the surveying parties, of which he had the immediate superintendence from that period for several years. This partial relief enabled Captain Colby to visit nine stations in Scotland during the year 1816, without the harassing distraction of mind which had hitherto attended the complicated charge of such distant works. In 1817, also, Captain Colby was for a long time in Scotland, and in that year measured, with the assistance of Mr. Gardner, the single base line of that kingdom, on Belhelvie Sands, near Aberdeen. The measurement of this base occupied from May 5th to June 6th, and Ramsden's steel chain was again the

instrument used. Its length, when compared with the unit Ordnance standard bar O, is found to be 26516·66 feet, and the length, as deduced from the Lough Foyle base, is 26518·99 feet, showing a difference of about $2\frac{3}{10}$ in five miles. Some of the old bases have afforded a better and some a worse comparison than the above; for example—

Hounslow Heath base, with glass rods, when reduced to the Ordnance standard, 1784 . . . . . 27405·06
Ditto, with steel chain, 1791 . . . . . 27405·38
Deduced by computation from Lough Foyle base . . . . . 27405·83

A result which may be considered unparalleled in geodesy, when the extent of the triangulation intervening between the two bases is considered.

Salisbury Plain, by steel chains, 1794 . . 36575·64
By Colby's compensation bars, in 1849 . 36577·95
Computed from Lough Foyle base . . . 36577·34

A result equally beautiful and illustrative of the general excellence of the instruments and work of the British triangulation.

Misterton Carr, steel chains, 1801 . . . 26343·72
Computed from Lough Foyle . . . . 26350·76

The difference here is considerable, and has been partly accounted for by the unfavourable ground; but it must be remembered that the comparison before quoted between this base as measured, and its length as deduced from other bases, was not so unfavourable as to render this explanation quite satisfactory—

Rhyddlan Marsh, steel chains, in 1806 . . 24515
Computed from Lough Foyle 24518

It is impossible not to see in these facts proofs once of the great care applied to the measure of the first bases, of the precision attainable b General Colby's compensation bars, and even by steel chains under due restriction, and of the super ority of the triangulation by which they have b linked together. This high character, indeed, v always maintained by the British survey, even w the results, which have been pointed out, were subject of so much discussion. M. Arago, when n suming, in a letter to Colonel Mudge, the subject c a connexion between the English, French, an Spanish measurements, says: "If this prop should appear reasonable, it will afford me further advantage of manifesting to you the confi dence with which your operations have ins those scientific men who are best able to appre them;" and Schumacher was so satisfied of excellency of Ramsden's sector, that on his r mendation the King of Denmark requested the of it for the celestial observations of the l arc: "The illustrious president of the Royal has informed me that you (Colonel Mudge) about to re-examine your celestial arc in the ing summer, and that you approve of lending sector to the King for the determination, also, of celestial arc. May I beg you to inform me v it will be necessary that I should apply to any person than to you, who have used the instrum

the beautiful work you have just terminated." It is remarkable that in this letter (1816) Schumacher anticipates what had now been satisfactorily proved, namely, that a considerable deflection of the plumb-line had occurred at Dunnose: "I have not seen," he says, "what Dr. Gregory has published on the subject, and I know only your observations by what has been printed in the 'Philosophical Transactions,' but from that I feel assured that the new observations will only confirm the old. You, who know the ground, are best able to judge where local attractions are most probable; but, on my part, I must confess that I should suspect them rather *at Dunnose than at Arbury Hill.* And further, it seems to me that in any hypothesis it would be very difficult to establish a perfectly regular figure for the earth. Such an hypothesis is, indeed, the least probable of any; and we ought not, therefore, to condemn observations because they tend to destroy an hypothesis which has so many chances against it."

It may be here observed that the instruments used on the Continent and in England for determining zenith distances were very different; as the sector, improved by Ramsden (several had been made of very large dimensions, by Sisson, at a very early date—for example, that of Pisa, 1765, and Dr. Maskelyne's, both of ten feet radius), continued the favourite instrument with the English geodesists, whilst the repeating circle of Borda has been generally adopted by French and other continental observers. The principle of the repeating circle, so far

as the mere reading of the limb of the instru
is concerned, is very beautiful, as it reduces
separate readings of a number of observations to
two, namely, one at the commencement and the other
at the end of a repeated angle, equivalent, in mag-
nitude, to the sum of the total number of separate
or individual readings, so that the error is reduced
to an inappreciable quantity by being di
amongst so many parts of the multiple, or repeated
angle; and it was therefore supposed possible to
attain the utmost precision with very small rep
ing circles. But it must be manifest that whilst
correcting the errors in reading of the divisions of
the instrument, nothing has been done towards cor-
recting the errors of observation or of bisection of
the object observed, consequent on the use of small
instruments; and further, that the difficulty of
guarding against any slight movements of the
centric circles during observation by any system of
clamping hitherto devised has not been remedied.
Schumacher, whilst admitting that the repeating
circles of Reichenbach far surpass those of the
French artists, still asserts, "that it is impossible to
rely upon any permanency in the constant error
when the limb of the instrument is placed in a
vertical direction," and adds, that he "should not
consider his work well finished, if the amplitude of
the arc were to depend only on observations m
with an instrument, the peculiarities of which were
as yet insufficiently known, and not on those made
with an excellent sector." It will be readily, there-

fore, supposed that any opportunity of bringing these two instruments into direct comparison with each other would be hailed with satisfaction by astronomers, and something in that respect was anticipated from the co-operation of the French and English geodesists, during the year 1817.

In October, 1816, M. Arago, on the part of La Place, communicated to Colonel Mudge the wish of that illustrious philosopher that the latitude of Yarmouth should be determined by the sector, in order to terminate at that point the French arc. "He sees," says Arago, "in the arc extending from Formentara to Yarmouth the means of determining with great precision the value of a degree of latitude at the 45th degree. The situation of the two extreme stations almost on the same meridian would render the result entirely independent of any flattening of the parallel, if such really exist. This operation, indeed—equally remarkable for its extent, for its object, and for its precision—would further have the more precious advantage of belonging equally to England as to France, and would become one day perhaps the basis of a uniform system of weights and measures." On the 4th of July, 1817, La Place himself writes: "Thanking you for your very kind reception of my proposition to terminate the French arc at Yarmouth, I must, at the same time, express my assent to your opinion that as it is now intended to extend the British arc to the Shetland Islands, Yarmouth may be replaced by the terminal station in these

islands, even though Formentara is about 1½
gree in longitude to the eastward of it. The di
ence in latitude between the ex po s
then be about 22 degrees, and as their d r
longitude is so very small, the geodesic o at
of France and England may be referr to t
without fear of any sensible error. It is
most important to determine t it e
tion selected in Shetland with the
and for that purpose to determine e zeni di
of as many as possible of the s, wl h ma
observed for altitude at Greenwich d Paris.
friend M. Biot will not fail, I am sure, to use e
care in determining the length of the pendul
that station. We are about to measure a gr
of the parallel between Strasbourg and Br ,
we shall then have all the data required for co
knowledge of the portion of the earth on whic
live—and surely, thus to study the earth is
better than to devastate it by conquests, how
brilliant and glorious they may appear. I am
lighted to hear that you propose to send the
sector to Brest, and I think that M. Arago will
you there, and assist in the determination o
latitude, either by observing with the sector, o
simultaneously observing with a good repe
circle; and as the singularity of an increas
the degrees from the pole to the equator, as
by your observations, has excited so much d
I would suggest that it might be advisable that
should afterwards repeat with Messrs. Arago

Biot, the zenith observations for latitude at Dunnose." With a view, then, to this co-operation between the French and English geodesists, so strongly advocated by La Place, and supported by the French Institute and Bureau de Longitude, M. Biot came over alone as a commissioner, on the part of the French, his colleague M. Arago being unfortunately retained in France by other business. The special object of this visit was stated by M. Biot himself, who, after having expressed his opinion that the French arc, when compared with the independent measurements of Svanberg and Lambton, was specially entitled to become the fundamental type of a system of measures, observes, "Since the rebellion of 1745, the English Government has felt the advantage of a detailed map of the three kingdoms to serve as the basis of works of improvement in peace and works of defence in war. The English triangulation, commenced by General Roy, and continued by Colonel Mudge, has already been carried from the south of England to the north of Scotland, so as to embrace several degrees of a terrestrial meridian, measured with excellent instruments. It was natural to wish that this arc should be joined to that of France, but the geographical position of England being a little to the west of our arc, it was feared that if all the terrestrial meridians were not similar the difference of longitude might affect the results deduced from such a junction. The Bureau de Longitude, therefore, wished that the pendulum apparatus which had been used in S]

and France should be also applied to similar trials at the principal stations of the English arc, as measures deduced from the pendulum are much less affected by small irregularities in the figure of the earth than are measured degrees." M. Biot subsequently adds: "When we had finished our experiments [at Leith] we were to have gone to the Orkneys to repeat them there, as the terminal station of the English arc, but Colonel Mudge, always anxious to render his operations as complete as possible, considered that it would be possible to connect the Shetland Islands with the Orkneys, by a triangulation embracing the intermediate islets or rocks of Faira and Foula—a plan which, whilst it extended the arc about two degrees to the north, also had the great advantage of bringing the English meridional arc two degrees more to the east, or almost in the prolongation of the meridian of Formentara." From what has been said, however, in a preceding page, it is manifest that M. Biot was in error in supposing that the design of terminating the English arc in the Shetland Islands was a sudden and after thought partly adopted, as it were, in reference to the French arc; as it has been shown, that Captain Colby had long before considered it a matter of course that the arc should be co-extensive with the triangulation, and therefore be terminated at the Shetland Islands; and that Colonel Mudge had finally adopted the same opinion there is not the slightest reason for doubting. The proposition of the French Board of Longitude was warmly re-

ceived, and in every way encouraged and promoted both by the Government, and by the scientific men of England. Biot arrived at Dover in May (1817), bringing with him his pendulum apparatus, a repeating circle by Fortin, an astronomical clock and chronometers by Bréguet, and having been spared all the vexations of the Custom House, proceeded at once to London, and thence, accompanied by Colonel Mudge, to Edinburgh. Here he found in Colonel Sir Howard Elphinstone, Commanding Royal Engineer, a most valuable and active assistant, as he at once gave the necessary directions for forming, in the most solid manner, the supports for the pendulum apparatus, and for putting up the observatory in Leith Fort: M. Biot expresses, indeed, his gratitude to that distinguished officer in the very warmest terms. It had been the intention of Colonel Mudge to assist in M. Biot's observations, but his health soon failing him, he was obliged to return to Woolwich, and his place was supplied by his son, Captain Richard Mudge, who was for the purpose called away from the Belhelvie base operations, in which he was then assisting Captain Colby. Biot speaks of him as "a young officer full of zeal, with whom he effectually completed his observations."

The observations fi ed, om
(tain Mudge, pro A , tl e
ei k for the She nds; ing l
t sojourn at that , where "he ienc
t nost marked h itality," Biot l e fi

become personally acquainted with Captain Colby, and it is greatly to be regretted that this intimacy did not ripen into friendship, but, on the contrary, ended in mutual distrust and dislike. The cause of an estrangement between two men, meeting for the express purpose of co-operation in a great scientific work, can scarcely be satisfactorily explained at this distance of time; but a reasonable conjecture may at least be formed of some of the springs of bitterness connected with it. Lieut.-Colonel Richard Mudge, who well remembers this interesting period of his life, emphatically declares, that had the ice once been melted between Biot and Colby, they would have mutually valued and respected each other; but it was fated that an eternal frost should separate th Biot, Colonel Mudge thinks, was vexed at not be asked to take part personally in the observa of the British geodesists, whilst they appeared to to him injurious strictures on their proceedi published in the "Caledonian Mercury." This latter charge Biot most solemnly denied, decl that he had neither connexion with the offen article nor knowledge of its author; and yet e Colonel Mudge seems to have clung to the l that he had written it. But in addition to t petty causes for distrust and jealousy, it w feared that the presence of Dr. Gregory did not c tribute to harmony. That able writer, then Pr of Mathematics to the Royal Military A had, with the sanction of the Master-G of the Ordnance, been invited by Colonel M

to join him in Scotland; and though no one could doubt the propriety and advantage of obtaining the assistance of his great talents at such a memorable epoch of the survey, there is nothing unreasonable in supposing that a person of the peculiar and warm religious feelings of Dr. Gregory was not likely to enter upon very cordial intercourse with the French philosopher, at a time when it was so customary to connect with that name, as a necessary adjunct, the notion of an atheist. Certain it is that Dr. Gregory attached himself to Captain Colby; and whilst the latter disliked and distrusted Biot, he, Biot, detested Dr. Gregory; and, indeed, it may be added, as another probable ground of this enmity, that Don Rodriguez, who had been so severely attacked by Dr. Gregory, in reply to his criticisms on the English arcal measurement, had been the asso ciate and friend of Biot in the triangulation of France and Spain. With all these elements of disagreement unhappily existing amongst them, the little party embarked in the Investigator surveying ship, commanded by Captain George Thomas; and the bitter feelings of Biot may be readily recognised in the fact that he cautiously avoided any mention of the name of Captain Colby in the account of his subsequent proceedings, merely observing: "When this great project, the extension of the arc to Shetland, had been resolved upon, it absorbed all our thoughts; and as the delicate health of Colonel Mudge did not enable him to engage in it, he entrusted its execution to one of the officers serving

under him." That one officer was Captain Colby, who had for so many years personally conducted the triangulation in Scotland, and who had so long kept his eye steadily on the rocks of the ancient Thule, as the fitting termination of the British arc. Great, indeed, must have been the irritation which could have prompted Biot thus to leave him unnamed, and even unnoticed, except as an ordinary subordinate; and under its influence it was to be expected that every trifling incident would assume an undue importance, as was the case on landing on the principal island, or "mainland," of Shetland, when Captain Colby and Mr. Gardiner proceeded directly across the island towards Lerwick, leaving M. Biot and Captain Richard Mudge to follow by another route and by themselves—an arrangement which appeared to the French philosopher a deliberate slight; though he had become more fully acquainted with his antagonistic colleague, he would have known that it was his invariable rule to take advantage of every such opportunity of seeing a country by leaving the more ordinary course, and crossing in a direct line every mountain peak which might fall in his way.

An evil, however, much greater than mere personal pique, occurred, on the arrival of the party at Unst, and that was no less than the disruption the plan of combined observations—Captain Colby observing with the sector in the small island Balta, and Biot swinging his pendulum, and obs ing with his repeating circle, at Unst. Neither

party can be fully acquitted of some share in the blame of this result; for though, without doubt, Captain Colby was the best judge of the most fitting site for the sector—considered also as a station of the triangulation—courtesy to an eminent foreigner, expressly come over to co-operate in a common design, should have suggested that a consultation with Biot on the best position for both their observations was very reasonable and proper. And yet no want of such courtesy was sufficient justification in itself for the adoption of a plan which has at least diminished the value of a comparison between the observations of the sector, of the repeating circle, and of Borda's pendulum, which would have been made perfect by a unity of both time and place. The propriety of the selection of Balta has been confirmed by subsequent observations, and M. Biot does not advance any sound objection to it in his published statement. After vividly contrasting, as two regions of the terrestrial are most widely opposed to each other in position and physical characters, the smiling garden-like fields of Valencia, its orange and citron groves, its perfumed air and historic reminiscences, with the rocky coasts, the craggy mountains, the damp, desolate, and bare surface, and the inclement climate, of the Shetland Islands, strewed over, indeed, with moss-encrusted stones, but neither adorned nor clothed by tree, shrub, or herbage, he states that: "On embarking in Scotland, it had been expected that we should have established ourselves at Lerwick, where Fort Charlotte would have afforded a most

favourable site for all our operations, but that we had been tempted onwards to the smaller island of Unst, as being at once half a degree more northwards, and somewhat nearer the meridian of Formentara. Arrived at Unst, we eagerly traversed the island, and met only the cabins of fishermen, with here and there the house of a farmer too small to receive the large English instruments; but fortunately the English Commission was provided with tents. At first it was proposed to establish the sector on the highest and most northern mountain of the island; but the difficulty of carrying up so great an instrument on men's shoulders—the only possible mode of conveyance—rendered it necessary to abandon that project, and the island of Balta was selected in preference. This little island is situated at the entrance of the principal bay of Unst, and serving as a breakwater against the sea, forms an excellent harbour, in which our ship was securely anchored, whilst the instruments and stores were landed in safety. At first I concurred in this arrangement, but on reconsideration, I thought of the furious storms to which the new station was exposed, its extreme humidity, the distance from any house, and the many difficulties in the way of forming a sufficiently solid foundation for pendulum experiments; and I feared that by persevering in adhering to it, I should endanger the success of my operations. In consequence, Captain Mudge and myself returned to Unst and availed ourselves of the hospitality most liberally offered by Mr. Edmon-

ston, the brother of Dr. Edmonston of Lerwick, who had himself shown us so many kindnesses, and given us letters of introduction to his brother. The pendulum apparatus was established in a large empty sheep-house with massive walls, and the observatory for the repeating circle was erected in the garden; but it was not till the 2nd of August that by the united efforts of the crew of the Investigator the large stones required for a foundation had been dragged to the spot, and the work of observation commenced." In all this there is not a word of complaint against the selection of Balta as the most fitting station for the sector or for the great theodolite: and there seems scarcely sufficient explanation given why more difficulty should have been experienced in establishing a fitting site for the pendulum and repeating circle, than for an instrument of the large size and delicacy of construction of Ramsden's sector. The result was a source of much mortification to Colonel Mudge, who thus writes (August 12th, 1817):—"I had the most perfect reliance on your judgment and good disposition towards me, and asserted publicly that though you were silent, I was positively certain that everything you did was right, and that I would stand by the consequences. I have now a full and comprehensive view of the question as it stands between us, and I *approve of everything* you have done. I think it appears pretty plainly that the sectorial and pendulum operations are anything but combined; as from the map I perceive that Unst is one island and Balta another; and I can

see no reason for supposing that M. Biot's experiments will last half as long as your observations, the rate of his clock being soon got, and the transit of one pen lum to the place of another is had, though the cl conceal the sun, or hide stars. But the state of case, as it affects your operations, is another t ter, and affords serious matter for consideration. The season is far advanced, even for this climate, but for Shetland still further, and offers the assurance that your operations will not be concluded without your having had many an ample taste of Shetland weather. That a great deal will be left undone in the way of observation with the theodolite, I naturally conclude will prove to be the case; but I do most earnestly hope that the observations with the sector will be finished by you, now that the in u- ment is up, with the same accuracy and excellence at Cowhithe Hill and Largo Law. I hope you will contrive, somehow or other, to compare the rate of your clock with M. Biot's, the reasons for which are obvious; your watch is a most excellent one, and may do very well to convey the time from one the other, and it is of prime importance that t should be done. I have very great confidence in clock, and the stability of its pendulum. I am fully aware, however, of the advantages which attend t French pendulum, and I know also where its advantages lie; but the whole operation connected with the pendulum of Borda seems likely to give the most satisfactory result. One great disadvan attending your removal from M. Biot is that a com-

parison cannot be made between the results of observations made for determining the zenith distances of the stars with the sector and circle of repetition: this is a very great misfortune.* I most particularly dwelt upon the necessity and advantage of this with M. Biot; and I am sure that very severe and heavy reflections will by and by be made on the ground of this not being done. It was the only opportunity we could have had in this country of fairly trying the question, which seems as if fate had decided on that matter being determined at Dunkirk. I had been in hopes to have seen the operations finished so early as to admit of the sector having been sent to Dunkirk this year, and I had obtained Lord Mulgrave's leave to take it there; but I see now there is little chance of its seeing the other side of the water till the spring. I should like to hear from you an account of the stations (if any) which may have been visited in Shetland for carrying on the distances from the south to Balta; and what you may have done in the way of observing at Faira and Foula, but perhaps these have not been visited; and I may perhaps think we shall have done not a little if the sectorial operations be completed, and a fair knowledge obtained of the manner of finishing the survey in the north with the greatest effect and advantage

* The Latitude of Unst by Biot is 60° 45′ 25″. The Latitude of Balta by the sector, 60° 45′ 1″·6, and adding to this 26″·9, the geodetic difference between the two sites, the latitude of Unst is 60° 45′ 28″·5, or 3″·5 more than Biot's determination.

to the general question. As to myself, I do not wish to exhibit the folly of useless complaint; but as the queen who gave up Calais said that 'that word would be found written on her heart,' I may say that Shetland will be written on mine, for I have never ceased to deplore, with the keenest recollection, the happiness that I thought before me nipped in the bud, and I sent home, as it were, invalided." On the 1st of August M. Biot and Captain Richard Mudge made the first experiment with the pendulum; and on the 17th they had completed eight of these experiments, and 270 observations for latitude. The health of Captain Mudge now began to give way, and he was at length persuaded by Biot to quit the island in a whale-ship, and return to a less severe climate. Biot being thus left alone, trained a young carpenter of Unst, who, like the Scotch in general, had been well instructed in reading, writing, and arithmetic, to read and note down the indications of the level of his repeating circle, as without such assistance he could not have continued his observations. The zeal and scrupulous accuracy of this young mechanic, which Biot took care, in the first instance, to verify by proper checks, were warmly applauded by Biot, who says, "With this assistance, at once timely and trustworthy, I succeeded in two months in obtaining thirty-six series of pendulum observations, each extending over five or six hours, 1400 observations for latitude in fifty-five series, taken both to the north and south of the zenith, and about 1200 observations of altitudes of the sun and

stars, for the determination of the rate of my clock; and from all this it may be conceived that I could do little but observe. In truth, I was obliged to restrict myself in calculation to what was necessary to satisfy me of the satisfactory progress of my observations, and to reserve the final calculation till my return to France; and it was well I did so, as, after all the time bestowed upon them, they are not yet entirely completed."

When Biot had terminated his observations at Unst, he wrote to Colonel Mudge, requesting that the Master General would give him official authority to take part in the sectorial observations at Balta, on the *perpetuation* of the principle which had brought him into England, but to this strange request, Colonel Mudge replied, "he was sure that Captain Colby would be happy to coalesce with him for the joint advantage of the work, and that he was a man so sound in understanding and every honourable principle, that M. Biot might safely throw himself upon him, persuaded that he would meet him on the same liberal principle that he, Colonel Mudge, should do." Biot did not, however, remain longer, but taking advantage of a small country smack, trading to Berwick, returned southward before the "Investigator" could be despatched to remove him. Making every allowance for irritated feelings, and even assuming that more courtesy should have been shown to him, it is evident, from his own statement, that Captain Colby could not have prevented the unlucky separation by any

possible change of his own arrangements. Had he encamped on the highest northern peak of Unst the difficulties in the way of M. Biot's arrangements would certainly have been greater than at Balta, and it was manifestly impossible to fix the trigonometrical station in the garden of Mr. Edmonston's house. Biot dwells indeed with delight on his residence at Unst, and attributes to his selection of that station the intimate knowledge he obtained of the warm-hearted hospitality, and other sterling qualities, of its inhabitants;—and says, "If I had remained on the rocks of Balta I should, without doubt, have gone away with all the prejudices of a foreigner; and have dwelt only on the sadness of the islands, the poverty of their soil, and the inclemency of their climate." Such indeed might have been the case, but he would have then succeeded in all the great objects of his visit by not only completing his pendulum experiments, but also by bringing into direct comparison the two rival systems of observation. Voluntarily he withdrew his own observatory and operations from the notice of the English party; and it seemed scarcely reasonable that he should then have sought to take part in their work. Steadily, however, they adhered to their rock; and accustomed to brave the fury of the storm, and to make themselves at home on the most rugged and cheerless ground, they patiently pursued their course until they had successfully completed their observations. Biot's experiments with Borda's pendulum, consisting of a platinum ball suspended by a wire from a knife-edge,

were subsequently confirmed by those of Captain Kater with the bar or invariable pendulum*, and were conformable in their results to the received or Newtonian theory of the earth's figure; but from a want of co-operation in the two sets of observers, they have not thrown any light on the physical or other causes which have modified the geodesical evidence of the English arcs. In 1817, Sir W. Congreve suggested to Colonel Mudge the use of instantaneous signals for the determination of differences of longitude, as noted in the following letter to Captain Colby: "I send you a letter that I have received from Sir William Congreve. It appears to me that he is providing what may be of great service to us, so that if you will come down on Monday with Mr. Gardner, we will, at night, attend Sir W. Congreve's together. If Sir W. Congreve can continue to exhibit by explosion combustible matter of great brilliancy, capable of being seen at 40 or 50 miles with ease, he will afford the means of finding the difference of longitude between two places much nearer than has ever yet been done by means of time. I wish you would write to Mr. Wolcott, and tell him to look out

* In this compound pendulum knife-edges are fixed transversely near the two ends of a flat bar, and when the number of vibrations is the same, on whichever of these edges the bar is made to vibrate as an axis, or the centres of suspension and oscillation are reciprocal, the distance between the two knife edges is the length of the corresponding simple pendulum. This coincidence is obtained by trial, the bar being supplied with a movable weight, which can be adjusted so as to alter he position of the centre of gravity.

from Hampstead toward Woolwich from eight until nine, and somewhat after, on Monday next." The first use of artificial signals was, however, of more remote date, as Picard employed them in 1671 to determine the difference of longitude between the tower of the observatory of Copenhagen and the ruins of the far-famed observatory of Tycho-Brahe, in the Island of Huen. In this case the signal was a fire lighted on the tower of Copenhagen, which was alternately concealed and exposed to view, the times of appearance and disappearance being carefully noted at the two stations; and as the distance was only six leagues, the plan answered tolerably well. At a distance, however, of thirteen leagues a fire of three feet diameter would not appear to the eye larger than a star of the third magnitude, so that with great distance the difficulty of suddenly masking the light of still greater fires would become almost insurmountable. In 1735, it was proposed by Delisle and La Condamine to use the flash from a gun, or even from a heap of exploded powder, and La Condamine proposed a change in the ingredients of ordinary gunpowder, so as to produce a more vivid light. In 1738, the French Academicians found that the light obtained by the explosion of six pounds of powder was distinctly visible at the distance of forty leagues. M. Cassini (third of the name) about the same time observed that the flash of a 24-pounder, fired on the jetty, near the lighthouse of Sete, was seen at Montpellier, although the mountain of St. Bauzel, 780

feet high, was directly in the line between the two places. Towards the end of 1739, Cassini and the Abbé La Caille determined in this manner the difference of longitude, 1° 53′ 19″, between the Hermitage of St. Clair near Sete, and Mount St. Victoire near Aix, the signals by the explosion, evening and morning, of charges of ten pounds, each of gunpowder, being made on the flat roof of the Church of Saintes-Maries, near the lesser mouth of the Rhone. In 1811 Baron Zach, from whose correspondence these details have been extracted, repeated this observation, but expended in the signals only four pounds of powder instead of ten pounds per signal, finding that signals were more instantaneous from the explosion of small than of larger charges. Baron Zach also used this method in 1802, in the survey of Thuringia, and thus noticed that a flash from a hill was seen, as a coruscation of light, fifty-five leagues, though the curvature of the earth concealed the hill itself. By the French, Italian, and Germans, this method has been subsequently used extensively, as for example in 1822, when the differences of longitude of the observatories of Vienna, Buda, and Munich, were determined under the direction of Professor Littrow. The signals were made by the explosion of charges of half a pound of powder suspended in a horn to a post six feet high, and fired by a common port fire. The arc of longitude between the observatories of Buda and Munich is seven and a half degrees, and the operation combined the use of two subsidiary stations, four signals (? three), and the two astronomical

clocks at the observatories; and Baron Zach states that the arc of longitude between Buda and Paris could have been determined by four stations, eight signals (? six), and three clocks. Before this, 1804, Baron Zach had exploded charges of six ounces of powder on the Brocken, which were seen on the Keulenberg, at the distance of 151 miles.

Common rockets were tried from Greenwich Observatory in 1775, but not being visible for more than six or eight miles, they are useless for such purposes. The Congreve rockets, however, more especially those improved by Captain Schumacher, a Danish officer, entrusted by the King of Denmark with his rocket department, were found to answer much better, as it was announced in Danish papers, in 1819, that rockets fired as signals on the small island of Heelm, on the Categat, had been observed with a telescope by Captain Schumacher's brother, the celebrated astronomer at Copenhagen, a distance of twenty leagues.

Baron Zach states (1822) that Baron D'Augustin, a colonel of the Austrian Artillery, had invented rockets which were capable of ascending to the height of nearly 11,000 feet, or more than two miles; that it was difficult to follow them in their ascent to the point of explosion with powerful telescopes of a small field of view.

It does not appear that Sir W. Congreve's experiment led to any immediate application of fire signals to the purposes of the survey, although the subject was frequently discussed by General Colby at a late period, and he always anticipated the use of Drum-

mond's Light in determining the differences of longitude of important stations, distant from each other, such as the observatories of Greenwich and Dublin. The French have subsequently used rockets, though with only partial success, in the great arc perpendicular to the meridian, between Brest and Strasbourg, before referred to, and the English and French, in determining the difference of longitude between Greenwich and Paris, as described by Sir John Herschel, in "The Philosophical Transactions for 1826." In 1839, the Rev. Dr. Romney Robinson, the well-known astronomer of the Armagh Observatory, determined in this manner the difference of longitude of the observatories of Armagh and Dublin, the rockets having been fired from the top of Slieve Gullion, a high mountain near Newry, and eighteen miles from Armagh. This mountain is 1,893 feet above the sea level, and though visible at Dublin, fifty-seven miles from it, is cut off from Armagh by an intervening ridge, so that the rockets were required to ascend more than 800 feet in order to be visible on explosion. All the details of elevation, bearing of hills, angles of elevation or depression, effects of refraction necessary to facilitate the operation were furnished by Lieutenant Larcom (now Major Larcom, Under Secretary for Ireland), from the documents of the Ordnance Survey; and it is not a little gratifying to those who have been connected with that great work to read the disinterested testimony of so able a judge to its general excellence. "It is," he says, "really wonderful how completely every

undulation of the ground has been registered in the survey. The altitudes sent to me, which must have been computed from the general sections, agree with observations in the most extraordinary way. A fact of another kind will show such persons as may not be acquainted with these things the precision of the Ordnance Survey. I set a telescope to the azimuth given for Slieve Gullion, and ascended the intervening hill with a theodolite, which I moved till, by signal from the observatory, it was in the line; then I took, with the theodolite, the angle betwe telescope and the pile on the mountain top, v our rockets were to be fired; it proved 180 exactly, or the three points were in one right l

It should be remembered that the survey commended had been planned and conduct by General Colby; and that the precision recorded been attained by surveying and plotting on a of six inches to a mile—a consideration which not to be lost sight of in discussing the proper for other surveys, or in considering the com expense of this and other surveys. That a survey furnished with accurate levels, so numerous exhibit every undulation or swell of the could be considered by any one useless for the preliminary examination of civil engineers, is deed scarcely reconcilable with the experience of Ireland, or with the ordinary deductions of r The Ordnance will doubtless be also gratified by testimony which Dr. Robinson bears to the excell of the rockets furnished from the Woolwich A

—"The rockets," he observes, "were remarkably ıod; *not one* burst, which certainly is a singular ıtrast to the French rockets in Sir J. Herschel's ı d Colonel Bonne's operations. Their average rise, the only evening I measured it, was 800 yards; they had, however, only four ounces of powder, but the part of the case which contained it weighed six ounces more, so that they actually carried a greater weight than the French." Much yet remains to be done to perfect the rocket as a military engine; but, even as the means of conveying signals at times and under circumstances when all other modes of telegraphing would be useless, their value should be deemed inestimable, when it is considered that a pound rocket will rise 1400 feet, a two-pound rocket will rise to that height and carry with it four ounces of bursting powder, and that Dr. Robinson succeeded in making some not heavier than the ıove, which carried four ounces of powder and rose the height of 4500 feet.

The present opinion of British geodesists on the value of the signal system of determining differences of longitude is thus given by Captain Yolland, R.E., in his able and elaborate treatise on geodesy, which forms a second part of the third volume of the new mathematical course for the R. M. Academy: "The method by instantaneous signals consists in two observers, at A and B, accurately noting the correct time by the chronometers of the appearance or disappearance of the signal agreed on to be exhibited from some intermediate station, C, visible from both

A and B. A careful person being stationed at the intermediate station C, with instructions to fire the gunpowder or signal rocket, or to cover or uncover the Drummond, Bengal, or blue light, at stated times, and to repeat the signal agreed on at certain intervals of time when the weather is favourable, so that the observers at A and B may be on the look-out at the proper time for the explosions, appearance or disappearance of the signal lights. A set of such observations will furnish a series of clock times for A and B, which may all be severally reduced to sidereal times from the observed times of transit of the selected stars, and the difference between such sidereal times is the resulting difference of longitude furnished by each particular observation. It is probable that the precision of the result, obtained by this method of determining the difference of longitude is greater than in that of any other process which has yet been followed." To these remarks of Captain Yolland, a caution should, however, be added, that the determination of the *absolute times* at the two terminal stations should be effected in the most perfect manner, and, if possible, by fixed instruments; but as regards intermediate stations, intended merely to transmit the signals by observing the *relative difference* of time of their exhibition, a good watch showing seconds, and which keeps a tolerably steady rate, is sufficient, as the interval of time between the exhibition of the signals of the two adjacent stations intended to be observed by one person in succession, ought not to exceed a few minutes.

The field labours of the memorable season of 1817 having been closed, Captain Colby returned to the Tower of London, and soon afterwards his opinion on the subject of publishing the map of Lincolnshire was requested by Colonel Mudge—the publication of the maps having been suspended during the war. His reply breathes the same liberal spirit which always manifested in discussing any great public
(on—as may be judged from the following letter February 2nd, 1818—"I have given what con-
ion I am able to the Lincolnshire survey, and I really can discover no good motive for rejecting the offer of the gentlemen of that county. It may, Lord Mulgrave has justly observed in his letter, proper to obtain some definite statement of their entions; but to what more proper object can the vey be directed, in time of peace, than to aid the neral improvement of the country: and how can at be done more effectually than in giving maps of se counties where the most beneficial changes are ing place? In the county of Lincoln, the spirit adventurous agricultural improvement has been eminently displayed. Individuals have im-ved their fortunes, and the nation has acquired tional resources from their efforts. New efforts now making in the same county, and these efforts y be rendered more efficacious by the aid of the rdnance map."—Captain Colby then examined in the several difficulties in the way of pro-eeding with the engraving of the Lincolnshire map, h as additional expense, interference with existing gements, &c., and having explained how easily

they might all be overcome, proceeds thus: "Having shown separately the consequences of commencing the Lincolnshire survey, I come now to a summary of the whole. Lincolnshire, with the exception of a very small portion, would be comprised in five sheets. A sixth, which would probably contain a small portion of the Spurn Head, would be necessary to square the map. I should propose giving it to the proprietors in three parts, containing two sheets in each. The district which would form the first part is nearly all surveyed at present; and, consequently, that part might soon be put in the hands of the engraver. It would consist of a portion of Norfolk, the Wash, an interesting part of the county of Lincoln, and small bits of the adjacent counties. Thus the proprietors would not be long before they were possessed of an useful specimen of the work. The regular progress of the general survey from south to north need not be interrupted or essentially retarded, if a small additional sum were granted on account of the Lincolnshire map: but the small additional sums advanced to expedite the work would be more than compensated by the increased sale which would arise from bringing out the map at the time it is wanted, and with the good will of the proprietors of the county. Should they commence a survey at their own expense, the improvement of their property would be diminished, and when the Ordnance map at length made its appearance it would find few purchasers. Their objects and ours would be alike defeated. I am sure I should be one of the

last persons who would propose a deviation from the regular course of the survey; but in the present instance, there seems to me no difficulty in preserving that regular course, and at the same time meeting the wishes and furthering the interests of the Lincolnshire gentlemen." Before, however, this object could be attained, several years were destined to elapse, and it was not until Captain Colby had become the director of the survey on the death of General Mudge, that the Lincolnshire map was finally published. The principal cause of the delay was the necessity of a rigorous revision of much of the survey details; and on this occasion Captain Colby exhibited that calm and imperturbable firmness, which was a striking characteristic of his mind, as no external clamour for the map, nor reproaches for the delay, could shake his determination not to publish until its accuracy had been fully established. For this purpose he sent Lieut. Dawson (now Lieut.-Colonel Dawson), and Lieut. Robe (the late Lieut.-Colonel Robe, R.E.), into the country to go over it sheet by sheet, and it was only after this verification that it was published. The beauty and excellence of the map, and its improvement in the harmony, and proportionate accuracy of its shading, obtained for it unqualified approbation; and it was considered by the best judges as a great advance in topographical science and art.

The difficulties which had been experienced in the preparation of this map for the engravers, or rather in the examination and adjustment of old survey

work, induced Captain Colby to devise a
promoting a more uniform system of sketching
drawing, as well as for ensuring greater accu
in the survey itself; and for this purpose
posed to place a certain number of assistants
Mr. Dawson, to be instructed by him in one uni
system of surveying, sketching, and drawing. T
assistants were designed to become, in their t
local superintendents, and thus to introduce
where efficient checks upon the accuracy of the w
Some of the gentlemen thus prepared did, for
time, good service on the survey; but General C
was unable to carry out the scheme in its int
and a different system of organisation has
quently superseded it.

In November, 1817, Messrs. Arago and Humb
accompanied by M. Biot, came to England with
pendulums, which were swung and observed a
Royal Observatory, Greenwich, in the presen
Mr. Pond, the Astronomer Royal, having been
viously experimented upon at Paris. M. Biot w
on the 24th November to Colonel Mudge, "I
not delay further replying to your kind propo
by saying that M. de Humboldt, M. Arago,
myself will be most happy to see the sector at
house at Woolwich, in anticipation of the grat
tion of using it with you at Dunkirk." In refe
to the two first of these great men, Humbold
Arago, Colonel Mudge, in notifying their arri
Captain Colby, observes, "I do not perceiv
slightest impression on their minds similar to

which animated the man when he wrote in the 'Caledonian Mercury.' Your report is quite the thing, and suits my purpose exactly, as well as being a sufficient proof of your consistency." And it may be here observed that the coolness between Biot and Captain Colby never extended to Arago, who, on the contrary, manifested towards him feelings of very strong regard. The project of taking the sector to Dunkirk, so anxiously looked forward to by both the French and English astronomers, was not carried into effect till late in 1818, as Captain Colby was actively engaged in Scotland from May 19 to September 17 of that year, having observed from nine mountain stations in that country during the interval. On September 1, Colonel Mudge wrote to Captain Colby, "The remainder of this letter must contain matters of official importance to us both, as you know the engagement under which I was made to place myself is now arriving towards fulfilment—I mean the Dunkirk expedition. I have received two letters from Biot, written with some anxiety upon this subject, which I had indeed anticipated by stating to him that on your return from Scotland we would both accompany the sector to France, at the same time telling him that it would be late in the season before we could effect that measure. Biot's reply was that it would perhaps be advisable to bring over the sector myself much sooner, as the observations were very simple, and might be made while you were going on with your operations in the North. To this letter I have replied with as much candour as I

hope I have always shown on every occ m-
accuracy and truth have been always y a
that I will not vitiate that character by at
that which I am not capable of performing. I h
told him that with the knowledge and judgment upo
the subject equal to what it ever has been in any
former period of my life, I am now not so equal to
the work of observation as yourself, and that I deem
it a just tribute to give you the honour of making
the observations at the south end of the arc, as wel
as the north, assured by so doing that the character
of the whole work will be best preserved, and my
own interests effectually served therewith. Now, I
do say that though you have no reason whatever to
be pleased with Biot—and God knows I have just as
little—yet I trust you will see with me the actual
necessity of our concluding the work of this year in
France. I feel that by so doing I shall conclude my
labours honourably, and I would be sorry after a lif
that has left me but little more to boast of
desire to do right, that I should conclude it
sistently." From this letter it is manifest that
Colonel Mudge anxiously desired that Captain C
should conduct the observations at Dunkirk, f
conviction on his part that there was no other
equally skilled in the use of the sector, or e
able to maintain the credit of the British geo
Captain Colby would have readily relinquish
task to any other person, so strongly did he re
what he deemed the unjust conduct of M. Bio
towards him.

University MICHIGAN

An extract from a letter of M. Biot to Colonel Mudge, of the previous 2nd of December, will in some degree explain and in great measure justify the feeling of Captain Colby, as there is no doubt it had been communicated to him—"As to the affair of the pendulum, I have only heard of it from yourself, not having had any participation in the experiments made at the Island of Balta. As to the discrepancies which you mention, as occurring between the results obtained from experiment in that island, and theory, they cannot be deemed a secret, as other persons have spoken to me about them before I had myself breathed a syllable on the subject. Captain Kater has pointed out to me the cause to which you consider that this want of success should be ascribed; but if I rightly comprehend your meaning, I do not see how the knowledge of the cause, which has rendered the observations erroneous, can be made a reason for forming a favourable opinion of them. Further than this, I judge no one. I restrict myself to the duty of making my own observations with all the care I can bestow upon them, and I leave others to *conduct theirs as well as their knowledge will permit.* I have not come to this country to act the part of a critic, and I have no desire to mix myself up with literary quarrels." These remarks, which could only have referred to Captain Colby, were certainly neither very candid nor very friendly, and, combined with the effort to induce Colonel Mudge to undertake the sector observations at Dunkirk without the aid of his colleague, strongly marked the disinclination of M.

[illegible] with Captain Colby; whilst on the other hand Captain Colby had little confidence in the French observers, and was always disposed to contrast unfavourably the respective systems of the two countries, the French results being, as he supposed, unnecessarily refined or improved, to such an object, while in the British survey it was laid down as an inflexible rule, that all observations should be recorded, and that none should be rejected, unless an entry of some cause of imperfection had been made at the time when they were taken. Notwithstanding, however, these personal dislikes, Colonel Mudge and Captain Colby proceeded to Dunkirk, and were there joined by MM. Arago and Biot, when the sector was put up in the arsenal. It is said that the French philosophers pronounced the sector "the finest instrument in the world;" but there is some doubt whether they really assisted in the observations, and it is certain that the desire of Colonel Mudge to bring the sector and repeating circle into direct comparison with each other, was not even gratified at Dunkirk, as such a comparison could only have been satisfactorily effected by a mutual interchange of the records of actual observations, before any corrections had been applied to them, and it does not appear that the French observations, in their original state, were communicated to the British observers, although a copy of the sector observations was transmitted to the French. In June, 1819, Schumacher writes thus to Baron Zach on the subject: "On my return from London, I hasten to inform you that Ramsden's

sector has safely arrived, and that I am about to put it up at Lauenburg. Colonel Mudge has communicated to me the latitude of Dunkirk, as observed with this instrument, but the place of observation was not the same as that at which the French observations were made. It was agreed that the observations should be reciprocally exchanged between the two parties, and Major Mudge sent a copy of his as soon as taken, but up to the time of my departure from London the French observations had not been received. M. Delambre told me, at Paris, that the latitude obtained by Colonel Mudge, with the sector, was in perfect accordance with that which he had obtained;" but on this statement Baron Zach remarks, in a note, "Up to this time we have had only reports, accounts, assertions as to this agreement, unsupported by any evidence or proof of their truth; we must therefore wait until the original observations have, as is customary in such cases, been published. Until then, no satisfactory judgment can be formed of this important work, on which the attention of all the learned men of the world has been fixed for twenty-five years." In December, 1819, Schumacher refers to his own observations with the sector, at Lauenburg, and mentions the visits he had received during their progress, from Gauss, Olbers, and Bessel. "To give," he says, "the greatest authenticity to these observations, and at the same time to testify to the English the gratitude we feel to them for the loan of the instrument, I send to General Mudge a copy, sheet by sheet, of my journal, the observations being

where a large company was, the report of Biot, exclaimed, 'God bless me! they never touched the instrument!'"* In this statement Schumacher should not have said that Baron Zach made the assertion of a daily communication, *on his own accord*, as the meaning of Schumacher's words, "Major Mudge communicated his observations as soon as they were made," was precisely the same. Making, however, every allowance for wounded feelings, and remembering that the report of Biot was written as a justification, it may be distinctly gathered from its admissions that the English astronomers communicated not merely a part, but all their observations, for when they sent *their registers*, they manifestly communicated the observations just as they were taken and recorded; they therefore enabled the French astronomers to compare the results with the data on which they depended, and in this respect not even M. Biot ventures to assert that there was reciprocity, as he merely says, that the latitude *deduced from the observations* was communicated. Again, too, it may be noticed, that there is no distinct recognition of Captain Colby in this report, although from the letter of Colonel Mudge, previously quoted, it must be manifest that he was the principal observer on the occasion, and his skill as such had been recognised by Zach in his note to Schumacher's letter, describing the sector observations in Denmark in the

* Lieut.-Col. Mudge confirms this statement that the French astronomers never availed themselves of the permission to observe with the sector though they had solicited it.

that which the French call *delicatesse*. The answer of the French is very artful. Zach had said (of his own accord) that you had *daily* communicated your observations. This point they take up, and their whole answer refers to the expression *daily*. 'It is not true,' they say, 'that an engagement was entered into by the English and French to exchange, day by day, their observations. It is equally untrue that General Mudge did communicate his daily. From the commencement of our union, and so long as it lasted, we freely offered to the English astronomers the use of our instruments, either separately or in conjunction with us; an offer, however, of which they did not avail themselves. On our part, we requested permission to observe with the great sector of Ramsden, and not only was it granted, but every necessary instruction for the use of that fine instrument given to us. They have communicated to us their registers, and supplied copies of a certain number of their observations: but this permission to use the instruments was not given, and this communication of the English observations was not made, until after we had communicated to General Mudge the latitude of our station, deduced from observations made with the repeating circle both to the south and to the north of the zenith.' Mark," continues Schumacher, "how artfully this is expressed. They do not say, *they observed* with Ramsden's sector, but every one who reads it will understand it in this manner; and I remember very well how our late friend, after having read, at a dinner at his house,

where a large company was, the report of Biot, exclaimed, 'God bless me! they never touched the instrument!'"* In this statement Schumacher should not have said that Baron Zach made the assertion of a daily communication, *on his own accord*, as the meaning of Schumacher's words, "Major Mudge communicated his observations as soon as they were made," was precisely the same. Making, however, every allowance for wounded feelings, and remembering that the report of Biot was written as a justification, it may be distinctly gathered from its admissions that the English astronomers communicated not merely a part, but all their observations, for when they sent *their registers*, they manifestly communicated the observations just as they were taken and recorded; they therefore enabled the French astronomers to compare the results with the data on which they depended, and in this respect not even M. Biot ventures to assert that there was reciprocity, as he merely says, that the latitude *deduced from the observations* was communicated. Again, too, it may be noticed, that there is no distinct recognition of Captain Colby in this report, although from the letter of Colonel Mudge, previously quoted, it must be manifest that he was the principal observer on the occasion, and his skill as such had been recognised by Zach in his note to Schumacher's letter, describing the sector observations in Denmark in the

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following terms :—" It is with this instrument that General Mudge made the meridional observations in England, and with which he and Major Colby repeated the observations at Dunkirk. *It is remarkable to me with what admirable skill Major Colby, who has lost his left hand, observes with this instrument.*" That admirable skill as an observer every one, who ever co-operated with him, must have witnessed and admired ; and his rigorous determination to maintain the utmost straight-forwardness in every proceeding of the survey was equally known to and respected by all who served under him. Early in 1820 died General Mudge, who had only recently attained that high military rank. To the scientific world he was best known as the able successor of General Roy, and as a mathematician of considerable merit, though still an adherent of the fluxional theory of Newton, and therefore not a convert to the differential calculus. The present writer, when at the Academy, enjoyed the occasional privilege of visiting at his house, and whilst participating in the friendly hospitality which he bestowed upon his young friends, and which was always distinguished by a warmth and simplicity which made them feel quite at home even with the lieutenant-governor, had ample opportunity of witnessing and appreciating that never-ceasing enthusiasm for his favourite sciences which he felt in his own heart, and desired on every occasion to instil into the minds and hearts of his young guests. Under his direction the survey maintained its high character ; and under his superintendence the

mathematics resumed that pre-eminence in the Academy, which they ought to possess in an establishment founded for the purpose of training pupils for a profession, which, though practical in its details, is scientific in its principles. The Duke of Wellington was then Master-General of the Ordnance, and actuated by that sound practical wisdom, which was one of his characteristics, he departed from the usual military routine of promotion by succession, and before appointing Captain Colby superintendent of the survey applied to the leading men of science for their opinion on the subject. Lord Fitzroy Somerset (now Lord Raglan) notified indeed to Captain Colby that such was the course pursued by the Master-General, and expressed his Grace's approval of the conduct of Captain Colby in abstaining from any private application, whether personal or through friends. The replies to the Duke's enquiries were favourable to the appointment of Captain Colby, as might have been expected; and Lieut.-Col. Hobbs, R.E., who was for many years an assistant on Scotch Survey, refers to the subject in a letter Ayr, Jan., 1825:—"I cannot help mentioning that about three years since I met Sir Humph Davy, at a dinner party in this neighbourhood; in speaking of the survey, Sir Humphry menti that soon after General Mudge's death he received note from the Duke of Wellington, requesting to name the person whom he might think t qualified to succeed the General: that in his reply the Duke he said he not only thought you the pe

best qualified, but it was in some measure your right, having devoted your whole life to this particular duty." An anecdote has also been preserved in the family of the late Sir William Robe, R.A., which will at least be deemed amusing and characteristic, even though some may consider it a mere traditionary legend. It is said then, that the Duke sent for the celebrated Dr. Hutton, perhaps the most practically effective professor of mathematics the Academy ever had, and asked him the plain question, "Do you think Captain Colby the best person to take charge of the survey?" "*The very best*," replied the Doctor; and then was about to maintain that position by sundry reasons, when the Duke stopped him, saying, "Thank you, Doctor, that is enough, you have fully answered my question, and I am satisfied." On the 10th of July, 1820, he was officially appointed successor to General Mudge in the superintendence of the Ordnance trigonometrical survey; and on the 16th of December of the same year he was named by Lord Melville a member of the Board of Longitude, also in succession to General Mudge. On the 19th of July, 1821, he became brevet-major; on the 29th of July, 1825, lieutenant-colonel; and on the 10th of July, 1837, colonel. In 1819 Lieut. Robe (the late Lieut.-Col. Alexander Robe) and Lieut. Dawson joined the survey, and were engaged with Captain Colby in the observations of five stations in Scotland. In 1820 the arrangements, consequent upon the death of General Mudge, induced a cessation of the mountain work. In 1821 Captain Vetch (now con-

sulting engineer to the Admiralty), and Lieut. Drummond (Under Secretary for Ireland at the time of his death), were associated with Major Colby in the observations of eleven stations, including the Islets Faira and Foula, as connecting links with the Shetland Islands; and it was after this season of extraordinary labour that Major Colby took part in the renewed observations in France. This second visit was the result of an application from the Royal Academy of Sciences, and Board of Longitude of Paris, to the Royal Society of London, expressing their desire that the operations for connecting the meridians of Paris and Greenwich should be repeated jointly by commissioners of both countries, nominated by the Royal Academy of Sciences, and Royal Society of London. Messrs. Arago and Matthieu were chosen on the part of the Royal Academy of Sciences, and Captain Colby and Captain Henry Kater on the part of the Royal Society; but though this expedition was not immediately connected with the ordinary operations of the survey the Duke of Wellington assisted it to the utmost, by attaching to it a party of Royal Artillery, and authorising the supply of tents, and every other necessary store. Captain Colby also took with him Mr. Gardiner, his former companion on the summits of so many mountains, and Captain Kater paid only a just tribute to the merits of one of the most efficient public servants which the survey ever had, when he said, that "to the talents, zeal, and exertion of that gentlemen, on various occasions of difficulty, they were much indebted." The original

stations of General Roy upon Fairlight Down, and near Folkstone Turnpike, which, as well as Dover Castle, had been connected with the stations on the French coast, at Blancnez and Montalembert, were not at first refound, and as the gun which marked the important station of Beachy Head had been removed, it was irrecoverably lost. The difficulty in refinding Fairlight station was the consequence of a change, since General Roy's time, in the position of the mill, the distance of which from the station, together with the angle between it and Fairlight church, had been given as means for verifying the site. Everyone who has been engaged in the troublesome operation of refinding stations after the lapse of many years, must have experienced difficulties of this kind, and have further ascertained how hopeless it is to seek aid under such circumstances, from the treacherous recollection of the inhabitants. A circular trace of the old mill revealed its former position at Fairlight, and when the centre of this trace had been adopted as the point of departure the station was found with such precision, that on digging under the theodolite, the wooden pipe by which General Roy had marked his station, made its appearance, at the depth of four feet. The writer of this memoir, having on several occasions been required to get over such difficulties, has met with many examples of the erratic character of mills, though unfortunately they did not always leave evidence equally tangible of their wanderings; and has been driven almost to despair when he has appealed to human testimony. As a preliminary

towards discovering the old signal staff at Holyhead, he sent for the man who for many years had been in exclusive charge of it, and was informed by him that it had stood "just at that spot, sir, where those stones are; why, sir, I watched it for many years, and saw it removed, and those stones were exactly at its foot." Who could doubt such precise information? more particularly as the place seemed a very fitting one! The theodolite was put up, but alas! all the angles were wild, and evidently pointed to a very different locality. It was gradually moved in this direction, and the angles began to improve, whilst the signal keeper kept loudly protesting that it was leaving the right spot. At length the angles became consistent, and on removing some of the surface stones, amidst the protestations of the man that it would be useless to do so, the butt-end of the old staff was found, and the unwilling keeper was forced to admit his error. On another occasion, in Anglesea, the published description represented the station to have been on the *highest point* of the hill, but the road and agricultural improvement had so changed the surface that two small adjacent peaks appeared, instead of one, and they were so vexatiously similar in height, and fitness for the purpose, as to render selection. Well, the first person who came up was the farmer who, for many years, had been tenant of the land, and he at once pointed out one of the peaks as the true site, declaring that he remembered well when the party was there, and a gentleman who had lost his left hand was constantly looking through

glass. Such testimony was irresistible; but the telescope having been put up flatly contradicted it: then came a neighbouring gentleman who said he had frequently visited Captain Colby, and looked through the telescope, and, with even greater confidence, pointed to the other peak as the right one. The telescope was shifted accordingly, but, strange to say, it denied the truth of the squire's statement, just as decidedly as it had done that of the farmer. Here was a dilemma! falling between two stools and not another in sight to rest upon! In such a condition of perplexity it was natural to appeal to the experience of Colonel Colby, and from him was received the laconic reply: — "Never mind the testimony of any one; trust to your instrument." And in truth this advice, though conveyed in terms of characteristic brevity, was most wise; and by following it a spot was soon found where the angles perfectly harmonised with those of olden time, although the plough had worked so great an alteration in the relative condition of the surface.

In order to facilitate observing across the Channel, compound lenses, of Fresnel's construction, then new to the scientific world, were used: and M. Matthieu, and Captain Mudge, put up the first one ever used in England at Fairlight. It was formed of numerous pieces of plano-convex lenses, arranged concentrically so as to form one compound lens, three feet in diameter, through which the light of the lamp, four inches in diameter, and composed of several rings of wick, was refracted. The light far

exceeded that of any of the British lighthouses, and appeared at forty-eight miles like a star of the first magnitude. This application of the lens led to its adoption for lighthouses in Great Britain, as Major Colby lost no time in communicating his opinion of its excellence and advantages to his friend, Robert Stevenson, the well-known engineer and constructor of the Bell Rock lighthouse, a rival structure to the chef-d'œuvre of Smeaton, the Eddystone lighthouse. Mr. Stevenson acknowledges the receipt of this description of the lens in his letter of the 15th of November, 1821:—"I was much obliged by the letter you sent me of the 1st inst., relative to the French lamp and lens. I wish you could put me in the way of getting a lens, as I would put it into Inch-Keith lighthouse for trial. It will answer for a revolving light; but having seen the Tour de Corduan I cannot well understand why they should use so many lenses of the description you mention. I had once an idea of communicating your letter to Dr. Brewster, when I was with him the other day; but I thought he might wish to make some use of it, and I was not sure how you might view this. I am sure you could not make a more interesting communication to the Doctor, either for the Journal or the Royal Society." The subsequent modification of the lens cannot be here noticed; in the hands of Mr. Stevenson they were soon and successfully applied, and he always continued to recognise the part which Major Colby had taken in promoting their introduction. Robert Stevenson died in July,

1850, but his son, Mr. Alan Stevenson, thus writes to Mrs. Colby, February 3rd, 1853:—"My father's intimacy with your late respected husband was very great, and when a boy I remember his almost daily visits to our house. There was no one whom my father more highly esteemed, and of whom I have heard him speak in higher terms as a man of great energy and devotedness in his duty. I well remember that he considered himself and the Lighthouse Board indebted to your husband for his promptness in calling his attention to the improvement of the French lighthouses, and begged me, in a history of the matter I was drawing up, to notice the fact. This I did at pages five and seven of the second part of my 'Treatise on Lighthouses,' in Mr. Weale's series. My last interview with General Colby was in Dublin in 1830, when on returning from a harbour survey in the west of Ireland I gave him some heights, which, not finding to agree with the Ordnance observations, he immediately (before I left him) made the subject of a communication to the officer on duty in the district whence I had come. I well remember that when I mentioned this, on my return to my father, he exclaimed with marked approbation, '*Just like the man;*' and then commented at some length on the leading points of his character." Such indeed was the invariable rule with General Colby; he never blinked an alleged fault, but in a manly straightforward manner proceeded to probe and rectify it.

Having fixed the lamps at Fairlight and Folke-

stone stations, the party crossed the Channel on the 24th September, 1821, and commenced their observations at Cape Blancnez, near Calais, and notwithstanding the prevalence of stormy weather and the casualties which usually attended it, such as the overthrow of tents, the dismounting for security sake of the great theodolite, &c., they completed them on the 7th October. On the 9th the observations were commenced at Montalembert, or Boulembert, a small fort near Boulogne, and were finished on the 14th, and the party recrossed the Channel from Calais on the 17th. The observations at Fairlight and Folkestone were then undertaken in succession, and completed by the 27th, when Captain Kater observes, "With great regret we bade adieu to our much-esteemed companion, M. Arago, who left us for Paris; and as the season was too far advanced for any further proceedings, the party returned to London." This feeling of almost affectionate regard to M. Arago was fully reciprocated by that truly eminent philosopher and honourable man, as is manifest in the warm and hearty expression of his sentiments towards Major Colby, in a letter to him of October 2, 1822. In 1822, the work of observation, commenced at Hanger Hill Tower, was resumed at Fairlight, in order specially to observe Wrotham Hill and Tolsford, on both of which lamps had been fixed, and in like manner at Folkestone. Tolsford Hill was the next station (at which the angle between Fiennes and Montalembert, on the French coast, was taken), and then Stede

Hill, Crowborough, Leith Hill, Wrotham Hill, Severndroog Castle upon Shooter's Hill, and Chingford followed, and completed the work of 1822, on the 18th November. In respect to this season's operations, it may be noticed, that the impossibility of observing one of the ends of the Hounslow Base, in consequence of intervening buildings, forced Major Colby and Captain Kater to connect their triangulation with the survey distance, Severndroog Castle to Hanger Hill Tower, as these were the nearest stations to the base which could be identified with precision. Chingford was a new station, established on the temporary meridian mark of the Greenwich Observatory, and was selected in order to make one side of a triangle coincident with the meridian, and thus to obtain the means of deducing the azimuths by direct comparison with that meridian. The assistance of Lieut.-Colonel Jones, Royal Engineers (the late most distinguished officer, Sir John Jones), was promptly and efficiently afforded to the party in raising the great instrument to the top of Severndroog Castle, and covering it when there with a shed erected on the top of the tower. Great difficulty was experienced at Severndroog in seeing the signal on Hanger Hill Tower through the smoke of London, but, observes Captain Kater, "Colonel Colby at length thought of a method by which this difficulty was overcome. Tin plates were nailed to the staff upon Hanger Hill Tower, the plates being disposed above each other in certain angles, so as to reflect the sun's rays to

Severndroog. This contrivance, which answers the purpose in a certain degree of the heliostat of Professor Gauss, was perfectly successful; each plate gave in succession a neat image of the sun, resembling a fixed star, which was seen through a smoke so thick that even the hill was invisible." Although this apparatus was simple in appearance, it was in every respect a true heliostat, and in ingenuity of contrivance by no means inferior to the more perfect machines of Gauss, or to the heliostat subsequently made by Drummond and used in the Irish Survey. It had indeed one advantage over them, that it required no assistant to watch and regulate it. In 1823, Colonel Colby finished the observations at Chingford with the Ordnance great theodolite, and thus completed the observing portion of this interesting repetition of General Roy's operations for connecting the meridians of the two great national observatories of France and England. Captain Kater published the results of this work in the "Philosophical Transactions for 1828," and it is most gratifying to observe the general coincidence between the new and the old distances, as determined in the present and in General Roy's operations; and although the ulti te object of this undertaking, namely, the direct c parison of the longitudes of the observatories Paris and Greenwich, cannot be fully attained until the results of the French portion of the triang tion have been published, Captain Kater took Ca as the starting point, and adding 0° 28′ 59″ west of

Paris to its longitudes, as given in the "Connaissance des Tems," the difference of longitude between Calais and Greenwich, as obtained by himself and Major Colby, namely, 1° 51′ 18·73″; he made the difference of longitude between Paris and Greenwich 2° 20′ 17·73″ in space, or in time 9′ 21·18″, which differed only 0·28″ in defect from the previous determination of Sir John Herschel by fire signals.

Captain Kater observes that "the truth of the preceding work wholly depends upon the degree of reliance that may be placed upon the base on Hounslow Heath; and as the accuracy of this is in some measure questionable, it is certainly desirable that a new base should be measured, to connect in the most unexceptionable manner the stations at Leith Hill and Wrotham. The measurement of a base has hitherto not kept pace with the progress of other geodesical operations; but the elegant arrangement which Lieut.-Colonel Colby has recently imagined for compensating expansion, and which has already been tried in Ireland with perfect success, leaves no doubt of the future accuracy of this most important part of trigonometrical operations." But gratifying as this testimony to the merits of the Colby compensating bars undoubtedly is, the comparison between the former measurements of the Hounslow Base, and its length as deduced from the Lough Foyle Bases, which has been given in a preceding page, proves that, so far as accuracy is concerned, the Hounslow Base may well compete with any other on record. The comparison of the standards is

course, another question, and would affect the measurement equally, whatever apparatus might have been used.

In this combined French and English operation both the great theodolites of Ramsden were used, the Ordnance theodolite having completed the observations of Chingford; and it may be stated, that originally these instruments were identical, and each provided with only two microscopes for reading the divisions of the limb. This arrangement was so far imperfect as it gave the reading of any one observed object only on two parts of the circle, or of any one observed angle on four parts; and in conformity with a suggestion of Mr. Pond, the Astronomer Royal, that it would be better always to arrange microscopes or verniers in prime numbers, as 3, 5, &c., so as to divide the circle into so many equal parts, Captain Kater had four intermediate microscopes applied to the Royal Society's instrument, which, with one of the old microscopes, divided the limb into five equal parts. Major Colby, either before, or simultaneously with, Captain Kater, had two additional microscopes applied to the Ordnance theodolite, so as to divide, in conjunction with the old microscope A, the circle into three equal parts, and thus to give each reading on three and each angle on six parts of the circle: and it may be suggested that it would probably have been better to have arranged the four intermediate microscopes of the Royal Society's instrument on the same principle, by making two of them divide the circle into

three parts with the old microscope A, and the other two with the old microscope B, and then to have compared the mean of A, E, F, with that of B. C. D. Both these theodolites were originally provided with a single semicircle affixed to one side of the telescope for taking angles of elevation and depression: but Colonel Colby replaced the semicircle by a circle of 12 inches in diameter, by which arrangement it became possible to reverse the telescope; and subsequently in the course of the Irish Survey, he added a second circle on the opposite side of the telescope, so that the microscopes on both sides could be read in each observation. This was a very great improvement on the original construction, and rendered the theodolite a very efficient instrument for vertical or altitude observations.

In 1822 Major Colby commenced the hill season on the Mull of Oe; but being obliged to attend personally to the observations required for the connexion of the observatories of Paris and Greenwich, the work of the year in Scotland was completed by Captain Vetch and Lieutenant Dawson, as it had been, in 1821, by Captain Vetch and Lieutenant Drummond. Ten stations, however, were visited in England in 1822, and observations for azimuth made at two of them. And it should be remarked, that M. Arago participated in the work of observing both in England and France; and thus made himself practically acquainted with the merits of Ramsden's instruments. In 1823, English stations alone were

visited: and from that time to 1838 the triangulation of Great Britain was suspended.

The many names of Engineer officers already cited must have shown that General Colby had contemplated a military organisation of the survey, even before the necessity of devising a new system for the Irish Survey induced him to adopt it in the fullest extension. Besides those named, Lieut. Renny, who retired from the corps at an early period, and was subsequently assistant professor of civil engineering at Trinity College, Dublin, was for a short time employed in Scotland; and Captain Gossett for a considerable time in England. And to these should be added Lieut. (now Major) Larcom, who in 1824 was first attached to the English Survey. At this period Captain Mudge acted as local superintendent, or executive officer, at the Ordnance Map Office, Tower; and during the absence of Colonel Colby, watched over the correspondence and engraving department, being assisted in those duties by Lieutenant Dawson; and in this and the few subsequent years the engraving of the English maps acquired the highest degree of excellence, and they were made more generally useful by a subdivision of the large sheets or plates into quarter-sheets. It must not be supposed that Colonel Colby was insensible to the probable result of so large an employment of military men, as it had been long before urged upon him, that under such an arrangement the Survey would ultimately

cease to be an independent department, and would be placed, like all other engineer commands, under the control of the Inspector-General of Fortifications. With him, however, the rule of duty was paramount, and considering, as he did, that a military organisation would be productive of incalculable benefit, he determined to adopt it, whatever might be the result in respect to his own authority, or to his permanent connection with the Survey. Had he acted differently, and continued in Ireland the old system of contract work of England, he would have retained his position as independent head of the Survey to the last moment of his life, just as his predecessors, Generals Roy and Mudge, had done. That he exercised wisely the power of selection of officers, at first confided to him without limitation, the names of those officers must amply prove, as scarcely one of them has remained undistinguished, either in scientific or in political life; and with them should be associated Captain Yolland, though a later selection, as he has proved himself so fully equal to the difficult task of giving to the world the published results of so much labour in a form which will maintain the character of the British Survey as a great scientific work.

In 1824 the Government determined to undertake the Irish Survey; and in that year the present annalist was first attached to that great work, and as he enjoyed during the early periods of the Survey the privilege of a most close and confidential intimacy with Lieutenant-Colonel Colby, and performed the

same functions, as regards the Irish Survey, as were performed by Captain Mudge in respect to the English, he can testify to the disinterested spirit which regulated in a similar manner all the appointments of the Irish Survey. Nor does he hesitate to declare his belief that, when the state of the work rendered it necessary to part from many of the officers who had so long and so ably served under him, Colonel Colby yielded rather to the necessities of the service than to any indifference to their labours or to their merits.

The object of the Irish Survey was more enlarged in its scope than that of the English, and it became necessary, therefore, to frame a system which should ensure a high degree of accuracy at a moderate expense; and further than this, Colonel Colby felt that such a noble opportunity of connecting with a topographical survey, all these collateral inquiries, by which the springs of national wealth are discovered and directed into their proper channels, ought not to be lost. The manner in which he planned and matured a system for these special purposes, whilst he steadily endeavoured to introduce improvement into every operation of the ordinary survey, will be shown hereafter; but for the present his steps will be followed only on the mountains and in the observatory. Accompanied by Lieutenant Drummond, Colonel Colby traversed Ireland from north to south in 1824, selecting the most suitable mountains for principal stations, and collecting data for determining the probable limits of altitude to be represented in

the map. To the importance of this latter consideration Colonel Colby was particularly alive, as he had noticed in the English map the want of harmony of tone which had been the result of engraving isolated portions before a scale of shades had been arranged for the whole map. Whenever the inch map of Ireland shall be published, it will prove the value of these preliminary inquiries, by forming one harmonious whole, in which independently of contour lines, every gradation of shade will correspond to a definite altitude. In 1825, the Irish Triangulation commenced on the Divis Mountain, near Belfast, and as a preparatory measure, Lieutenant Murphy was sent into Cumberland and Westmoreland, and Lieutenant Portlock into the Isle of Man, to recover the sites of the old stations, and to re-establish upon them either large staves twenty-five or thirty feet in height, or conical piles of stones from sixteen to eighteen feet in height. On undertaking a duty so novel to them, both Lieutenant Murphy and Lieutenant Portlock naturally inquired what had been the system adopted by their chief, and the present writer can therefore give this his first experience in survey duties as at least an imitation of the vigorous system of Colonel Colby. Landing at Douglas, his first object was to hasten towards North Baroole, and to locate himself at its base in a small public-house on the roadside, kept by Mrs. Looney. The next morning, as the month was June, he started with a small party of men, about three o'clock, for the summit, and was soon hard at work preparing for and erecting the

object. A few hours thus employed, and the free breathing of the wholesome mountain air prepared the stomach also to do its duty; and welcome therefore was the sight of Mrs. Looney, attended by her maidens as she scaled the summit, with kettle in hand, a store of burning fuel in an iron pot, and all the glorious appendages of a substantial breakfast. The repast was soon ready, appetite was boundless, and digestion sound, and yet the supply was inexhaustible. With new vigour the work was now resumed, and about eight o'clock, P.M., the party descended, when Mrs. Looney, whose heart was a generous one, served up a dinner, or supper, which, though it might not have suited the palates of a court of aldermen, was in quantity sufficient to gorge a company of giants. Day after day the same hours, the same labours, and the same feasting were repeated, when having completed North Baroole and Snea Fell, the author took his leave of Mrs. Looney, and was somewhat astonished when, for several days' lodging, for roasting-pigs of some months old, for gooseberry-pies more than a yard in circumference, and custard-puddings in half gallon jugs, and for all her journeys to the mount top, that lady demanded the *exorbitant sum of shillings!* Peace be with Mrs. Looney! and let ask, where should the wanderer with, as our p er brethren sometimes express it, a wolf in his stomach go for comfort, if not to the humble inn of Mrs. Looney, at the foot of North Baroole. South Baroole then followed; but alas! there was there no inn: liberal hostess, and though hospitality was as t

alive in the peasant's cabin—now the only resource —as it was afterwards found in a neighbouring mansion, hard work for a week on milk and oatcake served as a fast to correct the evils of the preceding week of feasting. Such scenes as these had been familiar to Colonel Colby for many years of his life; scenes wild and occupations laborious, it is true, but which derived from that very wildness, from that glorious sense of freedom which seems to swell the bosom as the fresh mountain air is inhaled, a charm which dispelled from the performance of duty the very thought of labour. Never, indeed, in twenty years of intimacy, did the author hear from the lips of Colonel Colby a single expression which could imply that in exertions beyond the powers of ordinary men he had done anything deserving of a moment's notice. During the time that these operations were in progress in England and in the Isle of Man, Lieutenant Drummond had proceeded to Ireland and prepared the Divis station for the great theodolite. The season had now fairly commenced under the immediate directions of Colonel Colby, as it was his invariable rule personally to initiate all his officers in their duties, and Lieutenant Drummond was the only one who had already passed through this training. Captain Orde (now Lieutenant-Colonel Orde), the late Captain Henderson, who subsequently, in conjunction with Mr. Maclear, measured a new base at the Cape of Good Hope; Lieutenants Drummond, Murphy, and Portlock, constituted the staff of officers of Engineers; and with them were associated about

sixty of the Royal Sappers and Miners, part of a force which, at the recommendation of Colonel Colby, had been trained at Chatham under Sir Charles Pasley, K.C.B., for survey duties, their instruction having been superintended by Lieutenant (now Lieut.-Colonel) Streatfield, R.E. This, though to most a season of instruction, was indeed a noble season, as the operations had, with Colonel Colby's usual comprehensive view of the subject, been made to combine the use and observation of every description of meteorological instrument, including all those recently invented by Professor Leslie, so that the camp on Divis became a school not merely of geodesical but of meteorological science; and though the difficulty of moving such delicate instruments from hill to hill, and preserving them from injury amidst the mountain storms, obliged Colonel Colby to abandon the use of some of them in subsequent stations, enough were retained to add the skill of practice to the theoretical knowledge which had been acquired at that first and most instructive station. The duty was divided amongst the officers according to a regular roster, and the officer of the day was called at the earliest dawn to rise, and kept watch on the weather. If the hill continued clear of fog, he called Colonel Colby at the moment when the light became sufficient to prepare for observation; and without an instant's delay he came to the observatory, and proceeded to observe all the more difficult and distant objects, which were practicable, leaving the officer on duty, when sufficiently trained, to observe minor objects, the other

officers assisting him by reading the microscopes. Except when absent selecting new stations, Colonel Colby continued this steady course of observation when the weather permitted, or of calculation in his marquee when clouds from the summit of the hill closed it up from external observation, as was occasionally the case for many successive days, without a symptom of weariness, until November, when he left Lieutenant Henderson in charge of the instrument, and the season terminated by the observation of Drummond's Light, on Slieve Snacht, a mountain in Innishowen, on which Lieutenant Drummond patiently prepared his oxygen gas, and watched and directed the light. The distance was sixty miles, and the light appeared like a star of the first magnitude, being visible by the naked eye. The station of 1826 was Slieve Donard, in the county of Down; and whilst on this occasion the author proceeded to Wales and Anglesey, to refind stations and erect objects, Lieut. Larcom proceeded to Slieve Donard to prepare it for the great instrument, and thus commenced his connection with a survey in which he afterwards filled so important an office. The author, as soon as he had finished his work in Wales, joined him there, and having put up the instrument, began the observations. Colonel Colby came to the station immediately afterwards, with Captain Pringle, who had been appointed to the Survey, as well for his mineralogical knowledge, he having studied at Freyberg under Mohs, as for his general talents, and with Lieutenants Drummond and Murphy, and con-

tinued until November, pursuing the same indefatigable course of observation, early and late, and regardless of the discomforts which more than one fearful tempest spread over the camp. He then left the mountain, and the author completed the observations of the station about the 4th of November, Lieut. Larcom reflecting to him with a heliostat from Anglesey, when the party descended, looking, as they wended their way through the deep snow, each carrying his load, like actors in the polar scenes of Parry, Ross, and Franklin. The personal superintendence of the great triangulation was from this time confided to the author, but Colonel Colby still continued to pay him an occasional visit, and to enter with his wonted ardour into the duties of the observatory; nor was it his custom to make these visits on stations of easy and pleasant access, but, on the contrary, he usually selected the most difficult and remote. It was thus that he appeared on Sawell, a mountain in a wild district of the county of Derry, early in a most gloomy morning, which had followed a night in which the wind had raged with almost unexampled fury, overturning in dire confusion the tents of the men though protected by walls of turf, whilst the rain deluged them, and obliging the author to dismount the great instrument, amidst the crash of all around, and in darkness only broken by the flickering light of a lamp, and remove it, step by step, at each lull of the storm, to the shelter of the cook-house lower down. Colonel Colby assisted in restoring it to its position, and seemed to enjoy the

spectacle of desolation, as it proved to him that his example of unshaken nerve on such occasions had not been lost upon his officers. Again accompanied by Lieutenant Larcom, he visited the author on Cnocanafrion, in the county of Waterford, a very picturesque station, as the observatory was placed on a stage, erected against the face of a rock, the actual peak of which was the station, and stood on the very brink of a precipice. From this noble and rugged mountain crag, Colonel Colby looked over the varied and vast expanse of mountain, plain, and sea before him with a fervid enthusiasm; and it was from the readiness and warmth with which he thus on all occasions identified himself with the feelings of his officers, and made himself one with them in thoughts and acts, that his visits were so welcome, so encouraging, and so profitable.

Turning from these recollections of unalloyed gratification, the visit to Kulteagh, or Culcagh, was one of painful interest, as Colonel Colby was then accompanied by the late Sir James Carmichael Smith and Lieutenant-Colonel Hoste, R.E., who were acting as commissioners of inquiry into the management and progress of the Irish Survey. Culcagh, a lofty mountain near Swadlinbar, on the borders of the counties of Cavan and Fermanagh, is rendered laborious, if not difficult of access, by a deep and much fissured bog at its base; and it was up this mountain that the commissioners were conducted by Colonel Colby, in order that they might see the system pursued in the great triangulation, and for

themselves question the present writer on its merits; and if, as they certainly did, they toiled, panted, and blowed upon their ascent, envying, no doubt, the elastic and never-faltering step of their more experienced comrade, they appeared, on arriving at the summit, to forget their fatigues and to be repaid for their exertions. On this mountain the new observatory was first pitched; the old canvas sides ing, with the exception of a rim at the top of about inches deep, been replaced by framed wooden tied together with iron clamps, and secured similar manner to the posts, or pillars, which ported the roof. This alteration was planned by the author; and though in itself very simple, gave to the observatory a degree of stability and security which banished from the observer's mind terrors which had before haunted and harassed in stormy weather. Not far from the great vatory stood a miniature one, exactly similar in struction to the other, in which were the meteorological instruments. The observator marquee, and the tents, partly sheltered by mocks of rock, and surrounded by stone wa the smoke-begrimed gipsy-like cook-house, fo picture in which the soldier visitors must ha nised many of the features of a military though lighted up by the fire of science and war. Both Sir James Carmichael Smith and Colonel Hoste expressed the highest admirat what they saw: but alas, whilst they prai executive officer, they overlooked or failed to

ciate the merit of the man who had planned the work which the other executed, and thus fell into that error which has been only too common in estimating the services and talents of General Colby.

The Survey of Scotland, which had been suspended for many years, was resumed in 1838, and on this occasion Colonel Colby once more appeared on the mountains, again to perform on Ben Hutich the part of an instructor, his assistants being Major Robe and Lieutenant (now Major) Robinson; and as this appears to be the last time of his taking the field, the record of this section of the stirring life of a man of ceaseless activity and boundless energy must here with a sigh be closed.

It is hoped and believed that enough has been said in the preceding narrative to illustrate the remarkable character and the services of General Colby in one branch of the duties he so ably performed; but were it not so, the vivid sketch of a season's doings, which Major Dawson has drawn up from the letters which he wrote at the time, and kindly contributed to this memoir, would more than supply the deficiencies. The author gives this sketch in Major Dawson's own words, and feels assured that the perusal of it will leave on every reader's mind a deep impression, not only of the zeal, energy, and abilities, but also of the moral worth of General Colby.

DEAR PORTLOCK,—

You have asked me for an account of a ye on the hills with our late chief, General Colby, d I will give you the first that I was out with

him, which I am the better able to do, as I find that the letters which I wrote to my family that year from the hills have by chance been preserved.

In the month of May, 1819, Lieutenant Robe (the late Lieut.-Col. Robe, R.E.) and myself were appointed assistants to Captain Colby on the Trigonometrical Survey; and on the 5th of June following I embarked, in charge of a selected party of artillerymen, the instruments and camp equipage, for Aberdeen, at which place Robe joined the party, and, after disembarking the stores, &c., and hiring cars for their conveyance, we set out on Tuesday the 15th of June for Corrie Habbie or Cathadh, a mountain in Banffshire, which had been selected by Captain Colby for our first station.

It was our intention to march only to Inveraric (sixteen miles) the first day; but the men surprised us with a petition to be allowed to go on to Huntley (thirty-eight miles); to which we assented. We were there joined on the following morning by Captain Colby, he having travelled through from London on the mail coach, with a rest probably of only a single day at Edinburgh; the journey occupying at that time four or five days and nights. This was Captain Colby's usual mode of travelling: neither rain nor snow, nor any degree of severity in the weather, would induce him to take an inside seat, or to tie a shawl round his throat; but, muffled in a thick box coat, and with his servant Fraser, an old artilleryman, by his side, he would pursue his journey for days and nights together, with but little

refreshment, and that of the plainest kind,—commonly only meat and bread, with tea or a glass of beer.

From Huntley Captain Colby proceeded with us on foot; and on the second afternoon we reached the base of the mountain in Glen-Fiddick, near to a hunting lodge of the Duke of Gordon. Here, by partially reducing the loads on the cars, and by the application of guy ropes to support them, and with the men's shoulders to the wheels, we climbed up as far as we could, and, having unloaded the cars, made an irregular kind of encampment for the night. It was a fine evening, and we had need, therefore, of but slight covering; and anything like luxury was of course out of the question. A marquee was pitched for Captain Colby, in which he slept, in his clothes, on a bundle of tent linings; and I, knowing no better, was content to put up with the like accommodation; but Robe, who had recently been with the Army of Occupation in France, like an experienced campaigner, set to work with his Portuguese servant, Antonio, who had also been with him on the continent, and soon put up his camp bedstead, and made himself much more comfortable—a lesson which I did not fail to profit by in my after experience.

On the following morning the really laborious part of the business commenced, that of conveying the camp equipage, instruments and stores, to the top of the mountain. Horses were hired for the purpose, and made to carry the packages slung like panniers over their backs, so far as the ground proved

tolerably even and firm : but when it became broken and hummocky, which is so commonly the case with peaty soils, or springy and wet, there was then no alternative but to unload the horses, and carry the things on the men's shoulders; and it was surprising to see the loads which some of them would carry for miles, over ground which inexperienced lowlanders might find it difficult to traverse on foot without any incumbrance. After encouraging the men for a while at the outset of their laborious undertaking, Captain Colby went on, taking Robe and myself with him, to the summit, where he selected a spot of ground for the encampment as near as practicable to the station, and also for the watch-tent at a point much nearer still. He then selected a suitable place for a turf-hovel, to be built on the sloping face of the hill with a tarpauling roof, in which to make a fire for cooking, and for drying the men's shoes and clothes, and to serve also as a place of shelter and warmth for the men in tempestuous and severe weather. When some of the tents had been brought up, and one or two of them pitched for present use, a party of the men were withdrawn from this duty, and employed in pulling down the conical pile of stones built round the station-staff, and in setting up in its place the observatory-tent. The requisite steps were then taken for securing the table or stand for the great theodolite; and the theodolite itself was then brought up with special care and fixed in its position.

In all these proceedings, here and elsewhere, Cap-

tain Colby invariably took an active part; and he would never sit down to rest or take any food or refreshment until everything had been satisfactorily accomplished and secured.

Corrie Habbie is elevated about 2,200 feet above the mean level of the sea. Like most of the other mountains in its neighbourhood, particularly to the northward and east, it is a long round-backed hill, rising gradually towards the south. It is of the quartz-rock formation, and covered with a heathy peat-moss, except on the summit, and a few bare patches on the sides, which show the whitened surface of the quartz-rock. To the westward, at a distance of about six miles, Benrinnes, a conical mountain, rises a few hundred feet higher than Corrie Habbie. Still further off, and extending towards the south, the Monagh Lea range rises to the height of 3,500 feet, and to the southward extends the Grampian range, with the mountain of Cairn Gorm and Ben Macdui in the foreground.

When the arrangements in the observatory had been completed, and the summit of the hill was free from clouds, every moment favourable for observation was anxiously caught by Captain Colby, and devoted to that service, from sunrise to sunset. At other times he imparted to Robe and myself a knowledge of Ramsden's great three-foot theodolite, and of its adjustments, as also of the mode of working and entering the computations; explaining still further the position and names of the principal moun-

tains and trigonometrical stations within the range of observation.

Monday, 21st of June.—After a stormy day the clouds suddenly broke away about seven o'clock in the evening; and at eight o'clock, under very peculiar circumstances of refraction, Captain Colby discovered and showed to us, through the telescope, a brig under sail to the northward, at a distance which he considered could not be less than 100 miles.

Monday, 28th of June.—At eleven o'clock, A.M., the thermometer, having previously stood at 50°, went down suddenly 5° at noon, when a tremendous storm of hail came on and covered the ground several inches in a few minutes. The hailstones were large and conical, with smooth convex bases and striated sides.

The hail continued till about one o'clock; after which snow fell for an hour or so, and then sleet and rain. We were forced to be out shovelling the hail and snow from the tents while the storm lasted, and when gone the men set-to snow-balling one another as a means of warming themselves—a rather unusual amusement at the latter end of June. At this this time the temperature at night was generally from 35° to 38°, and this was not complained of as being cold, but rather the contrary. With the thermometer at temperate the heat was considered oppressive.

Tuesday, 29th of June.—Captain Colby took Robe and a small party of the men on a "station hunt,"

or pedestrian excursion to explore the country, along the eastern coast of Invernesshire, Rosshire, and Caithness, and to erect objects upon some of the principal mountains, and select those which, from their position and circumstances, should be preferred for future encampments. That particular season of the year was usually taken for the purpose; because, owing to the tremulous state of the atmosphere, it is unfavourable for instrumental observations, excepting occasionally for an hour or so after sunrise, and for a like period before sunset; at which times, unless the summit of the mountain chances to be free from clouds and mist, nothing really valuable, in the way of observation, can be done. The opportunities afforded for the purpose are indeed extremely capricious and uncertain at other times also: it was no uncommon occurrence for the camp to be enveloped in clouds for several weeks together, without affording even a glimpse of the sun or of the clear sky during the whole period. And then in a moment the clouds would break away or subside into the valleys, leaving the tips of the mountains clear and bright above an ocean of mist, and the atmosphere calm and steady, so as to admit of the observations for which the party had waited days and weeks to be taken in a few hours. It may be imagined how perplexing it is at such times to receive visitations from the gentry of the neighbourhood, which otherwise would be highly acceptable.. And although nothing could, under favourable circumstances, exceed the good nature and patience which Captain Colby

showed even to the humblest of his visitors—gratifying them with a peep through the telescope at some familiar object; and then, by means of the prismatic and inverting eye-pieces, exciting their astonishment by showing them the same object apparently in a different direction, or standing upside down; so on the contrary nothing appeared to worry him more than the approach of visitors when we were really at work, and whatever might be their rank, he would then scarcely speak to them or show them even common attention.

Our post town, while on Corrie Habbie, was Huntley; and one or other of the men was sent there for letters and bread, when they could be spared for the purpose. The distance in a right line was eighteen miles, which Captain Colby considered to be equivalent to twenty-four.

Wednesday, 21*st of July*.—Captain Colby and Robe returned to camp, having explored all the country along the eastern side of the counties of Inverness, Ross, and Caithness, as well as the mainland of Orkney, and having walked 513 miles in twenty-two days.

Friday, 23*rd of July*.—Captain Colby took me and a fresh party of the soldiers on a station-hunt, to explore the country to the westward and northward of west. Our first halting-place was to be Grant Town, at a distance of twenty-four miles; and Captain Colby having, according to his usual practice, ascertained the general direction by means of a pocket compass and map, the whole party set off, as on a

steeple-chase, running down the mountain-side at full speed, over Cromdale, a mountain about the same height as Corrie Habbie, crossing several beautiful glens, wading the streams which flowed through them, and regardless of all difficulties that were not absolutely insurmountable on foot. Sometimes a beaten road would fall in our course, offering the temptation of its superior facilities to the exhausted energies of the weary members of our party; and in such cases freedom of choice was always allowed them. Captain Colby would even encourage such a division of his party and the spirit of rivalry which it induced, and took pleasure in the result of the race which ensued. Arriving at Grant Town in about five hours and a half we dined there, and proceeded afterwards along the valley of the Spey, by the high road, to the Aviemore Inn to sleep. The distance travelled by us that day was calculated at thirty-nine miles.

Saturday, 24th of July.—Started at nine o'clock. I was dreadfully stiff and tired from the previous day's scramble, and with difficulty reached Pitmain (thirteen miles) to dinner. The country helped me considerably, for it was beautiful—Rothiemurcus, on our left, being one of the loveliest places that I had seen. A good deal of brynny mountain ground, richly clothed with wood and plantation, rises immediately at the back of the house; to the right are green rocky hills, and not a tree to be seen.

Garviemore Inn, distant eighteen miles by the road, was to be our next stage, and I really thought

it was more than I could possibly accomplish that day, but Captain Colby said it was not. It was his intention, however, to leave the beaten road immediately, and, crossing a rough boggy tract of country to the northward, to gain the summit of Cairn Derig, a mountain about 3,500 feet high and about ten miles distant, and having built a large pile of stones upon it, to proceed thence again across the country to Garviemore, making the distance of course considerably greater and the journey much more laborious, as I thought, than by the road. I petitioned strongly, therefore, to be excused from accompanying him, and to be allowed to proceed quietly along the road with the sergeant and another man, who being equally tired had also blistered their feet, and to whom it was on that account allowed; but Captain Colby would not excuse me, and I had no alternative but to make the attempt, feeling sure that I should eventually be left upon the ground or carried home upon the men's shoulders. Captain Colby judged, however, from accurate observation and long experience, and he was right. I kept pace with him throughout the remainder of the day, and arrived at the inn at half-past eleven o'clock at night, much more fresh than at the end of our first stage the day before. The second day on such a journey is generally the worst, but the first had broken me in. I could have proceeded further if it had been necessary, and never experienced anything like fatigue throughout the remainder of the excursion. The distance travelled that day was forty miles.

Sunday, 25th July.—There being no church in the neighbourhood we strolled out soon after breakfast to see the country, being then in the very heart of the mountains. From the opposite side of the road to the southward the ground rises suddenly to the height of about 1,500 feet. This we ascended, and found, as is frequently the case, an eminence of greater elevation behind it. Having gained this second elevation a third appeared, and so on to others in succession, though, frequently, in pursuing our straight course we had to descend rocky valleys, and thus to lose, in a quarter of an hour, the elevation which it had cost half-an-hour's severe climbing to attain. In this way, however, we at length reached the summit of Bui-Annoch, a mountain rising suddenly from the wooded shores of Loch Laggan to the height of about 4,000 feet. From that point we obtained a splendid view of the western hills for which we were bound, a white and serrated range extending from the west to the northward as far as the eye could reach. To the north extended the Monagh Lea range, east and southward the Grampians, and to the south-west—distant about twenty miles—Ben Nevis, in his gigantic proportions, stood out boldly in the foreground, the acknowledged chief of this stupendous array. I have since traversed Switzerland, and the view of the Alps is, in my opinion, scarcely more imposing than this. In these days of steamboats and steam-carriages the journey to Garviemore would be amply repaid by the mountain view from the summit of Bui-Annoch. After

dwelling upon it for an hour or two, and refreshing ourselves with a copious draught from a pure spring surrounded with icicles and snow, we returned to Garviemore, having walked about four-and-twenty miles, and attained so great an elevation on the day which should have been our day of rest.

Monday, 26th of July.—Starting soon after daybreak we followed the road over Corrieharrack, a mountain about 2,000 feet high, in crossing which the road is zigzagged and marked with poles to trace its course in the winter when covered with snow. This mountain is said to afford the finest view in Scotland, and so it may to those who cannot go upon Bui-Annoch. Descending to Fort Augustus, eighteen miles, we proceeded thence in a north-westerly direction, twenty-two miles further, to a place marked Cluny upon the map. The first part of our route from Fort Augustus was along the line of one of the old military roads of General Roy, which, passing over an inferior mountain range, and descending into the valley on the other side, fell in there with the parliamentary road, made by the late Mr. Telford, as a communication with the Isle of Skye, and which arrives at this point from Fort Augustus by a very circuitous route. We then kept the road for the remainder of the day's journey, through a desolate mountain tract, without meeting any living beings but a few small birds. The inhabitants had been driven out to convert the district into a sheep-farm, and the remains of their habitations were occasionally to be seen by the road-side. There we could also

trace the sites of the encampments used by the workmen in making the roads; and, shut in as the road is by the mountains, a more dreary and melancholy journey it is impossible to imagine. Arrived at Cluny we found it to consist of only a few miserable mud hovels, one of which, being a public-house, was to be our abode for the night. The sitting-room we occupied in common with two drovers, who having arrived somewhat before us, had secured possession of the only two bed-places, which were built into the wall like the berths on board ship. The tail-end of a salmon was produced for our supper, but it was so stale that we were unable, even after our long walk, to eat it, and we thankfully partook of a mess of oatmeal-porridge with goat's milk in lieu of it; after which, upon three or four wooden chairs, placed as evenly as the earthen floor would permit, and with our knapsacks for pillows and our short walking-cloaks for a covering, we settled ourselves to rest for the night.

Tuesday, 27th of July.—It may be inferred that our departure was not delayed much after daylight this morning, and that on our arrival at Invershiel, at the head of Loch Duich, to breakfast, we partook with no slight satisfaction of a fine salmon, brought almost alive from the fishery in front of the inn. We proceeded afterwards to Scour Oran, a high mountain to the north-east, being one of the serrated main range before spoken of; and, having built a large conical pile of stones on its summit, we returned to the inn at Invershiel to sleep.

Wednesday, 28th of July.—Crossing the Kyle Rea ferry into Skye, we proceeded to Broadford and thence to Sconser, a distance about two-and-thirty miles, and the following day made an attempt to reach the summit of the Coolin Hills, but were completely foiled in the attempt, and that was probably the only instance in which Captain Colby was ever so foiled. Nothing that I have seen can, for savage grandeur, bear comparison with these mountains. They appear to be of a basaltic formation, about 3,000 feet high, the upper portion of which, for about 100 feet, is a perpendicular and partly overhanging black rock, which, under the influences of time and the seasons, has broken away and completely covered the ground with débris for about a thousand feet.

This mass of débris, standing at the steepest angle that will retain it in position, requires but a trifling additional disturbing cause to set a large mass of it in motion; and it was necessary to use the greatest possible caution with our party in traversing it obliquely to avoid the displacement of even a single block of any magnitude, which might bring down the superincumbent mass like an avalanche to sweep us away.

Not being provided with ladders or ropes the perpendicular rock at the summit effectually baffled our efforts for several hours to find a crevice by which to ascend it. We gained, however, a ridge which reaches out from the perpendicular cliff with a superb column at the extremity of it, and so narrow is this

ridge that we were obliged to sit astride upon it, in which position little more than the strength of an infant was required to hurl a stone to the bottom of the corrie on the south side without impinging upon the face of the cliff, a depth of about 2,000 feet. After admiring for a while the magnificence of the prospect, and the dreary and all but chaotic scene around us, we returned to our inn, gratified above measure with what we had seen, though disconcerted with our professional failure.

Friday, 30*th of July*.—The higher mountains being enveloped in clouds Captain Colby hired a boat, and we sailed to Portree, a small town about ten miles to the northward, whence we proceeded to the range of hills above it, and, having erected a pile of stones upon one of them, we returned again to Sconser.

Saturday, 31*st of July*.—A bright morning at daybreak, and we were on foot again to make a fresh attempt on Scour-na-Marich, another head of the Coolin range, which Captain Colby had singled out for the purpose on the former occasion, and this time our effort was crowned with success. Having built a large pile upon it, we returned to our inn to breakfast, which by that time we stood much in need of, and, hiring a boat, we proceeded direct to Jeantown, at the head of Loch Carron, on the west coast of Rosshire.

Sunday, 1*st of August*.—In the course of the morning, as we were looking at the map to ascertain our position and the probable course of our journey

for the ensuing week. I so far forgot the sacred nature of the day as to commence whistling some light air. Captain Colby very properly checked me in so doing, explaining to me the deep sense of veneration with which the people of that country regard the observance of the Sabbath, and the next day I was informed while on the march, by one of our men, that he had been urged by the landlord to come to me and beg me to cease whistling, dreading lest some judgment should otherwise fall upon his house. There can be no doubt that I was wrong, and that Captain Colby and the landlord were right. We explored that day the mountains to the north-eastward, and built piles upon some of them, passing on afterwards to the upper end of Loch Maree, thence by boat to the lower end of the Loch, and by road to Gairloch at night.

Those who have traversed the mountains on the western coast of Scotland in the autumn, may be familiar with the effect produced by the bites of the midges, which swarm there at that season. The heat also then being intense, it was our practice in walking to put our coats and waistcoats into our knapsacks, and thus, with our shirt necks thrown open, and our sleeves tucked up, we were exposed in a peculiar manner to the baneful attacks of those vedomous insects. On the occasion referred to we suffered very severely; our arms, necks, and faces, were covered with scarlet pimples, and we lost several hours' rest at night from the intense itching and pain which they caused. Even at the inns we had

frequently to smoke in our bedrooms and over our meals to drive these insects away.

Tuesday, 3rd of August.—While at breakfast this morning, we received a visit from Sir Hector M'Kenzie, the chief proprietor of that district, from whom we afterwards learnt that the landlord of the inn had hastened to apprise him of our arrival, intimating that we ought to be the laird's guests and not his. As the country was then covered with mist, down to the water's edge, Captain Colby had no hesitation in accepting the proffered hospitality of our kind host, and we spent a few days most happily at his house, during which time the atmosphere, fortunately for our personal comfort, though not for our professional duties, continued unchanged.

In one of these days we were suddenly summoned to assist in restoring a drowned man, a poor shoemaker, who, after a long day's work in repairing our men's shoes, had gone to bathe and got out of his depth. Captain Colby at once undertook the management of the case. He was familiar with the ordinary rules of the Humane Society, and, taking off his own coat, he proceeded himself to do, and direct others to do, what was necessary, for fully three hours; but unhappily without effect. The body had been too long in the water, and life was extinct.

The sun at length broke forth again, and we proceeded on our march. We were supplied by our kind host with an introduction to a friend of his, at Letterew, on the northern shore of Loch Maree,

which secured us a hospitable reception there also; and, had there then been a prevalence of misty weather, or had our object been pleasure, we might, I believe, have remained, or have been passed on in a similar manner from one hospitable mansion to another for almost any indefinite period. For one night only could we profit by it on that occasion; and, after exploring the country to the eastward, and building piles upon the mountains which were best placed, we descended to Loch Fannich, where, at a comfortable inn on the roadside, we spent the evening with the proprietor of the estate, who occasionally made it his residence during the shooting season. He informed us, that in the previous season, some sportsmen from England, to whom he had granted permission to shoot, killed at the rate of fifty brace of birds to each gun per diem, and left the birds where they fell upon the ground.

The next morning we proceeded onward to Beauley and Inverness; thence, on the day following, to Grant Town; and on Saturday, the 14th of August, returned to the camp on Corrie Habbie, having walked 586 miles in twenty-two days, including Sundays, and the days on which we were unable to proceed from bad weather.

In addition to the ordinary hill fare of boiled mutton, broth and plum-pudding, our dinner that day consisted of boiled salmon and grouse, with vegetables and fruits of various kinds and of the finest quality; ale, porter, and wine. For this we were indebted to the liberality of the Duke of Gordon,

who was then at Glen Fiddich. He came up frequently to see Captain Colby; and his bountiful provision was continued to us while we remained on that hill, and included also the men who were there encamped with us.

Wednesday, 25th of August.—The thermometer in camp yesterday stood at 75° at noon. This day it was 45°, and we were hard at work in the observatory from eight o'clock in the morning till eight at night. The distant hills were extremely clear, except to the north, and we saw the pile on Ben Nevis very distinctly through the telescope, at half-past seven o'clock, after sunset, the distance being seventy-five miles in a right line. The sudden change of 30° temperature in one day was very sensibly felt by us in our exposed situation and with the instruments in our hands for so many hours. But we were thus enabled to complete the observations on this and the three following days.

Tuesday, 31st of August.—We arrived at Inverness last night, and found the town in commotion, expecting the arrival of Prince Leopold of Saxe Coburg. He came this day with the Marquis of Huntley, and as we chanced to be at the same inn, and in the next room, Sir Robert Gardner, who was travelling with the Prince, called on Captain Colby, and introduced us both to His Royal Highness. Nothing more was requisite to ensure an invitation for us to the entertainment provided for him in the evening. On that occasion we were fortunate also in meeting with Captain, the late Lieut.-Colonel English, R.E., then

commanding the Royal Engineers at Fort George, who promised to visit us on our next station, Ben Wyvis, and bring up with him Colonel, the present Sir John Fox Burgoyne, G.C.B.

Friday, 3rd of September.—We arrived at the summit of Ben Wyvis this afternoon. The mountain is about twelve miles N.W. from Dingwall, and 3,400 feet high. The top of the hill was covered with a dense fog, which continued with heavy rain and wind for several days. Mr. Adams, the Rector of the Academy at Inverness, and Captain M'Claren, of Dingwall, ascended the hill with us; and after partaking of such refreshment as we could give them, they departed homeward, and I accompanied them through the fog, and over the worst ground, They contrived, however, to miss their way afterwards, and wandered about over the rough boggy ground until one o'clock in the morning, when they fortunately reached the place where two of our round tents were pitched, about half way between the station and Dingwall. Here they were glad to eat a mess of oatmeal, mixed with cold water, and sleep in a blanket upon the baggage, which was piled together for the night.

Friday, 10th of September.—Barometer 26·487 at noon. Thermometer 43°, and at night 39°. This and the preceding day were fine, and we were at work in the observatory from six o'clock in the morning until seven in the evening; the field of observation including Cairn Gorm, Ben Nevis, the hills in Skye, and the long range of precipitous

mountains extending northward, almost to the north coast, with a considerable tract of cultivated ground extending eastward to the Murray Firth. The whole constituting a panoramic view of no ordinary kind.

Sunday, 12th of September.—Three of the tents blown down last night. I was despatched to Fort George this day—twenty-nine miles—to prosecute, on the morrow, two of our men for absenting themselves without leave, and striking a non-commissioned officer. I returned to Dingwall on Tuesday, and found that the party had left the hill, and gone northward. Starting by the mail on Wednesday morning I overtook them at Latheron in Caithness.

Saturday, 18th of September.—Erected the observatory on Bein Cheilt, a hill about two miles west of Latheron, and 1,200 feet high. The ground a perfect peat moss, and the country around it very uninteresting, the Scarabin hills and the rocky pass of Caithness, to the southward, being the most pleasing objects in the landscape. Ben Wyvis, in the distance, was seen covered with snow.

Wednesday, 22nd of September.—Completed the observations last night, and packed the instrument in its waggon. This day we travelled back about forty miles to Goltspie, and proceeded to Bein Loch cas na Cairoch, a mountain about four miles to the westward of that place. Here again the ground was a perfect bog, and wetter even than at Bein Cheilt. The season too had now changed; we had

frequent and violent storms of hail, rain, and wind, which occasionally threw down some of the tents; but in the intervals the atmosphere was clear, and allowed of the instrument being constantly at work. September is in fact considered one of the best months for the Trigonometrical Survey; and contemplating a speedy removal to another station, Colby ordered the camp to be pitched about a mile and a half from the observatory, at the outlet of a secluded lake, which was reported in the neighbourhood to be haunted.

Acting upon the suggestion thus offered, some of our men prepared a large turnip lanthorn, which at night they set floating at the upper end of the lake with a light westerly breeze. Attention was quickly called to this unexpected appearance, and some of the most venturesome of the party set out along the shore of the lake to ascertain the cause of it. The night being perfectly dark, the light, seen from the water's edge, appeared to be always on the opposite side of the lake, and the party made the complete circuit without obtaining the desired information.

It was then proposed, and by some of the party rather reluctantly assented to, that two parties should set out—one on either side of the lake—and this time, by the merest chance, as the two parties by their shouting found themselves nearly opposite to one another, and each thought the phantom within the other's grasp—the light suddenly went out—and the disappointed and disconcerted inquirers returned to camp, with the conviction that "such things should

not be enquired into." The next morning, very early, the lid of the camp-kettle was picked up in the little stream near our tent doors; and I much question whether, to this day, those who saw and heard of it are persuaded that it was only a successful trick.

Wednesday, 29th of September.—The observations were finished last night. This morning being fine, the tents were taken down and packed dry, and sent by water to Tarbat Ness, the north cape of the Murray Firth. The great theodolite in its waggon was sent round by land, and Captain Colby, Robe, and myself, proceeded also by the road through Tain. There we had the gratification of witnessing a Highland meeting,—Glengary, with his brother chieftains and their pipers; and, as a consequence, we obtained bad accommodation and little rest.

The station at Tarbat Ness is only 200 feet above the sea and 500 yards from it, upon hard, dry ground, and the observations occupied but a week or ten days. The weather was now daily becoming more stormy and wet. The mountains were all covered with snow, and the trigonometrical season was declared to be at an end.

After seeing the instruments safely packed, the keys of the provision chests were, according to established custom, given to the men, who received also from Captain Colby a carte blanche to provide themselves with a farewell feast. The chief dish on such occasions was an enormous plum-pudding. The approved proportions of the ingredients being, as we were

told, a pound of raisins, a pound of currants, a pound of suet, &c. to each pound of flour; those quantities were all multiplied by the number of mouths in camp, and the result was a pudding of nearly a hundred pounds weight. Every camp kettle was in requisition for mixing the ingredients —some breadths of canvas tent-lining were converted into a pudding-cloth,—a large brewing-copper was borrowed to boil it in,—the pudding was suspended by a cord from a cross-beam to prevent its burning, and it was kept boiling for four and twenty hours—a relief of men being appointed to watch the fire and maintain a constant supply of boiling water. A long table was spread in three of the marquees, pitched close side by side and looped up for the purpose—and seats being placed also for Colby and his subs., we partook of the pudding, which was excellent, and withdrew, after drinking "*Success to the Trig.*"

Such had been Captain Colby's course of life for many years before I joined the Survey, and the season of 1819 was nearly his last. He was out in 1821 with Vetch, Drummond, and myself, in Orkney and Shetland, and upon the two lone islands of Fair and Foula, on the last of which Captain Colby experienced a severe inflammatory attack, and had to send to Lerwick, on the east coast of Shetland, for leeches, his sufferings in the meantime being almost beyond endurance. In 1822 he was out again with Vetch and myself on the west coast, and taking me with him, explored the whole range of the Western

Islands, from the Mull of Cantire to the Butt of the Lewis, and returning to Isla he slept for one night only or two in camp at the Mull of Oe. In 1825 he was on Divis, and in 1826 on Slieve Donard, in Ireland, and that was, I believe, the last year that Captain Colby was encamped on the hills for any length of time, until the resumption of the Survey of Scotland in 1838.

Yours very truly,

R. W. DAWSON.

To persevere in exertions so arduous in their nature
d degree for so many years, and yet simultaneously
with them to direct and control all the other opera-
of the Survey with the utmost clearness and
ch, required an union of great physical powers
of a sound intellect, seldom met with in the
person; for be it remembered that whilst by
ple and precept on the mountain summit General
Colby was exciting in all his officers a spirit of enter-
prise and a habit of persevering endurance, which
enabled them to triumph over all difficulties, and to
le at what many would have called privations, he
enabled to bring the English Map to that state
perfection, both of drawing and engraving, which
forth the eulogistic testimony of Lord Mont-
and Sir Roderick Murchison, in their evidence
e the committee of 1851. Lord Monteagle ob-
ved,—"There is nothing in which the progress of
provement is more visible than in the English
; but taking the English Map, we will say some

of those beautiful sheets in South Wales, which are exquisite, as well as some of the later sheets which they have published, I do not think you can go in map-making beyond that.—A map which is really well engraved, as the modern maps of the Survey of England really are, are chefs d'œuvre of engraving as well as of drawing, exquisitely drawn and engraved." And Sir R. Murchison said,—"I beg to express my most decided conviction that they produce nothing on the continent equal to our best maps, as recently published in this country by our own Ordnance Survey, of which I lay what I consider a beautiful example before the committee, of a part of Wales, which I think so perfect a delineation of the country that nothing more can be called for." Unquestionably in this branch of the work he availed himself of the careful inspection of Lieut.-Colonel Mudge and of Lieut.-Colonel Dawson; and as regards the Maps of Wales, of the great artistic talents of Lieut.-Colonel Dawson's respected father Mr. Dawson; but in this, as in every other improvement, his mind expanded to the full range of requirements which a great national work demanded, and enabled him to appreciate and encourage, as well as to direct, the talents of others in securing them.

In the Irish Survey this great faculty of General Colby was still more strikingly exhibited, and will be traced through the several stages of that work which may be emphatically called his own; as he not only planned the system on which it has been so successfully accomplished, but even invented the most im-

portant of the instruments, the compensation bars for measuring bases, which were then for the first time employed. But before closing this record of patient endurance, of steady perseverance, and of unparalleled activity and energy, in order to study the high constructive and administrative talents of General Colby as exhibited in the Irish Survey, it is only right to point out more distinctly the maxims of conduct which were naturally based on the example he exhibited, and which became the inflexible though not written rules of the Ordnance Survey.

He never allowed pleasure to interfere with duty, and hence it was that the observer clung to his mountain top with unshaken resolution, and never allowed the allurements of the low grounds to tempt him from the scene of his labours, or to cheat him out of one moment of good observing weather.

He carefully shunned any act or word which should outrage national prejudice or feeling, and this principle of forbearance enabled his officers to pass through the wildest portions of Ireland, in the most disturbed times, without exciting ill feeling or inducing opposition.

He devoted every available moment of fine weather to observation, and when baffled by fogs or storms, he calmly seated himself in his tent, and as if in the quiet of his office, proceeded with his calculations. In short, when engaged in duty, he bestowed all the energies of his body and mind upon it; and there cannot be a doubt that in this great principle of

action he was closely followed by all who served under him.

Is there any one then so blind or so unjust, as to praise the successful results of the combined and unwearied labours of so many able and conscientious men, and yet to withhold from the man in the track of whose example they had trodden, and by the fire of whose spirit they had been kindled into enthusiasm, that honour to which his memory is so justly entitled?

PART II.

HAVING followed General Colby to the last scene of exhibition of that personal energy which was so remarkable a feature in his character as a practical geodesist, the narrative must be retraced back to the epoch when Major Colby was required to extend the operations of the British Survey to Ireland: and in order to estimate correctly the magnitude and the difficulties of the task thus imposed upon him, it is necessary to compare together the objects of the previously existing and of the projected surveys, and to consider what means were then available for, or suitable to, the purposes of the prospective work.

It is not until civilization has made considerable progress, and the value both of time and labour has begun to be estimated with scrupulous precision, that the importance of good maps can be fully appreciated. Until then the bold huntsman or the hardy peasant pursues his way over rough and dangerous tracks, regardless both of the labour and of the difficulties of his journey; but when at last by the pressure of an increasing population and the multiplication of its wants, men are taught to economise every mo

ment of their own time, and of the labour of their horses and cattle, as being an element of production, the loss of which must be attended by a corresponding loss in the productive value of their property, they cannot long be blind to the importance of such maps as will guide them in laying out their roads and their canals, or assist them in studying the physical condition and the local peculiarities of the country they inhabit and the soil they cultivate. The successful execution however of extensive national maps depends on certain scientific principles which have been founded on an accurate knowledge of the figure of the earth, and it is not therefore surprising that the production of really good or accurate maps should have been reserved for an age of scientific excellence. In this country, indeed, as has been already shown, a great scientific operation, simple in its details but grand in its results; namely, the triangulation for determining the length of an arc of the meridian, as an element in estimating the figure of the earth, was the precursor of the national survey, and supplied the necessary data for combining together the surveys or plans of detached portions of the earth's surface, and for projecting them correctly as one whole in the map of an extensive country. This first survey, commenced as it was in detached fragments, had for its object a general representation only of the country, and though the field work was plotted on the scale of two inches to a mile, the map itself was engraved and published on a scale of one inch to a mile, which was manifestly in-

sufficient for practical purposes; for though in a favourably situated district, such as Wales, a map on this scale, sketched and shaded with the skill of a Dawson, may have proved sufficient for the geologist in tracing out the great features of the ground, a similar map in a country of less marked reliefs would have proved inadequate even to so limited an object. Beautiful therefore as maps upon this scale have been, and can be made; and valuable as they are to the traveller, to the general student of a country, or even to the road maker, they are not sufficient for the wants which have grown out of the modern refinements in agriculture and the improved modes of general communication, or have been consequent on the pressure of an increasing population. Waste of time and waste of space can no longer be tolerated, and hence it is that the value of minutely detailed maps has at length been felt and acknowledged. Nor was it only in the object of the work, that the early survey differed from the survey as it now is; it differed from it also in the principle of its execution. The original survey having been grafted, as it were, upon an independent scientific work, was local, and detached in order of performance, and as the importance of a great national survey was at first only partly recognised, the annual parliamentary grant voted for it was small, and the work proceeded under all the disadvantages of a slowly protracted survey, an interrupted publication of unconnected maps, and a tone of shading and style of execution varying, though improving, in its progress.

Subsequently, indeed, the work was viewed as a whole, and every care was taken after the publication of the map of Lincolnshire to revise the first published maps, to lower their depth of shade, and put them in harmony with the last; but still the defect of a system, in which every successive map represents a portion of the country in a different condition from the preceding one, must cling to this great work, until at a future period it shall undergo a general revision, undertaken simultaneously over the whole country, and be thus rendered a faithful record of the condition of the country at some one definite epoch.

The British Survey has just passed into the transition state between a collection of detached and not very harmonious works, and a work executed on uniform principles as one whole; and the maps had assumed, under the immediate superintendence of Lieut.-Colonel (then Captain) Mudge, R.E., and Lieut.-Colonel (then Lieutenant) Dawson, R.E., who were ably assisted by the intelligence and artistic skill of Mr. Baker, the chief engraver, that purity of style and just graduation of shade, which have raised them to the first rank amongst the most beautiful specimens of topography of the present age, when the attention of Government was powerfully directed to the wants of Ireland, hitherto overlooked as regarded the national survey. The object however of the Irish Members of Parliament was not to require the extension of the British survey and British map to Ireland, but to ask for a work which should serve as a basis for a general valuation and

be practically useful in the adjustment of the local burthens of taxation, and it is therefore evident that they had adopted a much more sensible view of the advantages of an accurate survey and map than had hitherto been taken by their English brethren, the reason of this superiority of judgment being fairly ascribable to the fact that Ireland was already in possession of a survey of no mean character; one, indeed, which, considering the time of its execution, must be considered a work of very great merit.

The history of the survey of Ireland, commonly called "The Down Survey," by Dr. William Petty, A.D. 1655-6, edited for the Irish Archæological Society by Major (now Lieut.-Colonel) Thomas Askew Larcom, R.E., one of its most distinguished members, enables the enquirer to study the object and peculiarities of that remarkable work, and to perceive the natural connection between it and the modern Ordnance survey of Ireland; and this work of a friend and brother officer will therefore be freely used for that purpose.

The great objects of the Down survey were the measurement and the distribution of forfeited lands; but as the ancient people of Ireland had been persecuted and despoiled before the time of Cromwell, so also had surveys for similar objects been previously found necessary. The surveys of Tipperary taken in the time of the Earl of Strafford (1639), and called the Strafford survey, were of this kind, and under the sanction of the Lord Deputy and Council, were adopted by Dr. Petty, who however

undertook to introduce all such amendments as time had rendered necessary, for "it was considered that many houses and improvements were now demolished, which were, anno 1639, standing; and many wet grounds, heretofore pasturable, now become wholly bog, with other like alterations, which might have proved a grievance to the army, and consequently a review was thought necessary." In a Report on the Strafford survey made by Mr. Benjamin Worsley, Surveyor-General, and Mr. Miles Simner to the Commissioners of the Commonwealth it is thus described, "We have perused certain small books bound up in parchment, and entituled: No. 1, Barony of Ikerine; 2, Eliogarty; 3, Kilnemanagh; 4, Kilnelongar; 5, Ileagh; 6, Upper Ormond; 7, Lower Ormond; 8, Arra; 9, Owny Mulrian; 10, Ownybeg. On the outside of which books are set down likewise the names of the parishes respectively belonging to that barony. In the inside of the books, before every parish, are set downe the names of the jurors, being generally six in number, and underneath the said names, this memorandum within, that they being all duly sworne upon the holy Evangelists, have set forth the bounds and meares, names and by-names, of all the quarters, plow-lands, and other denominations of lands lying in the parish, together with all the owners and proprietors of the said lands, their names and by-names, and to the said information have at the end thereof subscribed their names.

In the next place is sett downe the names of the

surveyors who admeasured the said parish, with this memorandum, that each sworne admeasurer for the parish doeth present, uppon his oath the true quantities and qualities of all the several lands lying in the parish to be as followe, and to the said presentment hath, at the end hereoff, subscribed his name.

The method and proceeding in the description of every parish is as followeth :—

1st. The number of surrounds made by the instruments, in each parish respectively, is sett downe together with the quantity of land contained in each surround, according to the denominations, as one plowland, $\frac{1}{2}$, $\frac{1}{3}$, or $\frac{1}{4}$ of a plowland, &c.

2nd. A description of each surround, more particular, according to the name of the land so surrounded; the quality of the said land as arable, pasture, meadow, timber-wood, shrubby wood, and bogg; and this again into waste and into that which holds a proportion as $\frac{1}{2}$, $\frac{1}{3}$, $\frac{1}{4}$, or $\frac{1}{6}$ in value, as we conceive to that which is profitable and good; 4th. The names of the proprietor or proprietors who have lands within the said towne soe called or distinguished, or a note of the said lands itts being in controversy; 5th. the quantity of acres in the said towne distinguished according to the quality; 6th the number of reference, both to the county and to the baroney, and to the parish map.

3rd. At the end of each surround is an observation made of what castles, houses, mills, or other edifices, as also what mines or other emoluments were found upon it.

Wee further humbly certifie that, besides the sayd bookes, wee find a very fair county map, containing the several barronyes before described to be admeasured; as alsoe other smaller maps of particular barronyes, and of particular parishes, most of which, soe far as wee can discover, are very entire and perfect. The said plotts or maps expressing alsoe the quality of the said land, whether arable, pasture or meadow, &c., and how the same is respectively situated in each land." These extracts give a most favourable view of this section of a survey in the early part of the seventeenth century, and of the common sense objects it was intended to fulfil.

Such as the Strafford survey was, Dr. Petty adopted it, having first employed Dr. Patrick Raggett to go over it carefully, comparing the ancient measurings with his own new test measurements, and Dr. Raggett thus reports the results of his investigations. "I, Patricke Raggett, of Thurles, in the county of Tipperary, having been duely sworne, doe hereby certifie that the barronyes of Balleboy, Kilcarsy, *and others* on the King's County, have by myselfe or sufficient assignes and partners, been surveyed and admeasured according to the printed instructions given unto me by Dr. William Petty, viz., by returning the true quantity, quality, figure, situation, name, proprietors, bounds and buildings uppon, and of all and every the parcells and surrounds of lands directed to be admeasured, together with the names of the mearesmen, and of their dwellings, who shewed the said lands. And have reviewed, exa-

mined, and compared the survey and admeasurement of the barronyes of Upper Ormond, Lower Ormond, of Owney and Arra, of Owneybeg, and the territories of Kilnemanagh and Kilnelongurty, in the county of Tipperary, by surrounding and tracing over the meares of all and every denomination of land within the said barronyes, by the help and with the assistance of a jury of the country, and doe attest the same to have been well performed, according to the best of my care, skill, knowledge, and information. Given under my hand, this 10th January, 1655.—PAT RAGGETT."

In this instance, however, as will generally be the case, the adaptation of old work to new, proved far more troublesome and very nearly as expensive as an entirely new survey would have been. It appears indeed that Mr. Worsley, the Surveyor-General, had shunned the use of these previous surveys when engaged on the new survey, before the undertaking of that work by Dr. Petty, and that one motive at least for their adoption by the Doctor was to avoid the disputes which might have grown out of a comparison between two distinct surveys, for it is said, "that the Doctor understood that the books of reference which were wanting were gotten into the hands of some of the officers whose lots were like to fall in Tipperary, who, in case of disagreement (between the new survey now to be made and that already in being) to their disadvantage, would oppose that very reputeable survey of Strafford sorel against the Doctor's." After all the trouble of e:

amining the Strafford survey and comparing it with the civil survey, as well as of reconciling the names and distributions of land, and the expense of a review of the work by Patricke Raggett, "the said old survey did not yield much advantage to the Doctor uppon the whole matter, that is, uppon downe admeasurement and subdivision, taken both together, there having been soe much ventured to try it by the above mentioned previous examination and reviews. So that, in briefe, this old survey gave the Doctor only an occasion to play at hazard, and he had the good fortune to win, though not one hundred pounds." He, however, escaped much litigation by fusing the Strafford survey into his own, and that doubtless reconciled him to a measure of which he manifestly disapproved.

The condition of the topography of Ireland anterior to the epoch now under examination is thus summed up by Lieut.-Colonel Larcom: "Before the time of Petty, except the material compiled into the early maps of Ireland by Boazio, Ortelius, Norden, Blaeu, and others, the only detailed surveys of any magnitude were those of the King's and Queen's Counties, about 1630; the county of Londonderry, by Raven; and the Strafford survey. Worsley was carrying on the surveys for grants and forfeitures, which have been sufficiently adverted to already as 'grosse surrounds;' but it remained for Dr. Petty to originate the idea of connecting the separate operations, into a general survey of the three provinces which were not comprised in the Strafford survey.

His great step was making territorial and natural boundaries the main objects, instead of estate boundaries alone; because the former were permanent and enduring, the latter in their nature fluctuating, and destined to change by the very purpose for which the survey itself was made."

The object which had rendered such surveys, as the last enumerated in this passage, necessary, was one of the age, and continued unaltered notwithstanding the change in the character and persons of the governing body of the state. In the reign of Charles I. the Earl of Strafford, when Lord Deputy of Ireland, directed those surveys of Irish forfeited estates to be made which subsequently bore his name, and again in the great rebellion of 1641 a new motive for forfeiture was discovered, and new surveys became necessary. The lands thus obtained by forfeiture were neither retained as Crown property, nor transferred by royal grant from one great proprietor to another, but were in part allotted to the soldiers in lieu of their arrears of pay, and in part to those adventurers who had been induced to contribute large sums of money towards the expenses of this international war. Such had been the projected arrangement of the Monarchy; and it was not only adopted by the Protectorate of Cromwell, but extended so as to include the subsequent arrears of the soldiery; the people of Ireland receiving at that time about the same treatment, and being equally an object of legalised prey, whether governed by monarchists or by republicans.

The preamble of the Act for the "Satisfaction of the Adventurers for Lands in Ireland, and of the Arrears due to the Soldiery there, and of other publique debts," is thus worded: "Whereas, many well-affected persons, bodies politique and corporate, did subscribe and pay in, upon several acts and ordinances of the late Parliament, divers considerable sums of money by way of adventure towards the suppression of the late horrid rebellion of Ireland, which said sums of money were, by the said acts and ordinances, appointed to be satisfied by several proportions of the lands of the rebels there, as soon as the said rebellion should be appeased; and whereas also several other great sums of money are grown due, and in arrear unto the officers and soldiers who have been employed in reducing the said rebels, and to sundry other persons, either for arrears yet unsatisfied, of moneys lent, or provisions or other supplies furnished for the publique service; and whereas, by the blessing of God upon the forces of the Commonwealth, the said rebels are subdued, and the said rebellion is appeased and ended, and it is hereby declared to be appeased and ended;" so that it may be readily conceived that the motives for confiscation must have been very powerful, when the land and other real property were destined to replace money in the payment of the troops, and in other public transactions: nor did the land of Ireland pay alone for the cost of its own conquest, as may be judged from the following passage of the Act, "And be it further enacted by the authority aforesaid, that

in case the moyety of the said ten counties shall not be sufficient to satisfie the debt of the said adventurers, then the remainder thereof shall be satisfied by such lands as are forfeited in the county of Louth within the province of Leinster, excepting the barrony of Atherdee, and what shall be defective in the other moyety of the said ten counties, to satisfie the arrears of the army in Ireland, that have accrued and grown due since the fifth of June, 1649, together with such other arrears as become due unto them for *their service in England* before the said fifth day of June, 1649, shall be made up and satisfied unto them out of the surplusage of the moyety of the ten counties allotted to the adventurers, in case any such surplusage shall appear to be, and out of the county of Louth, or out of the forfeited lands of other counties in Ireland"—by which passage it appears that arrears of pay due for service in England were also liquidated in Irish land.

It is unnecessary to dwell longer on this painful part of the subject, as it will be readily understood from what has been said that no ordinary caution was required in the survey of land which was about to be distributed amongst so many eager, and as regards the soldiers, either already or about to be disbanded, literally hungry claimants; whilst therefore the Act of 1652 entitled, "An Act for the Settling of Ireland," created the necessity for a survey, provision was made for its execution by the Act of 1653, by order of council which that Act confirmed, and by the instructions drawn up by the commissioners

which it approved. The work was undertaken by Mr. Benjamin Worsley, who had come from England for the purpose and was appointed Surveyor-General, and that portion done under his direction bears the double name of Civille and Grosse survey, which is thus explained by Lieut.-Colonel Larcom, "In regard to the designations Civille and Grosse survey, which occur so frequently, it will be seen that the Civille survey was the terrier or list of forfeited lands, prepared under the commissioners appointed by the commission of 1st June, and Act of 26th September, 1653. The Grosse survey was the designation by which the surveys ordered by the above commission are referred to in the Acts;" and it may be added that the word survey in its most ample and mosts atisfactory sense should never be confined to the mere topographical delineation of a country, or the simple field work connected with it, but should embrace, as in this case, the preliminary operations of the examination and determination of boundaries, and the subsequent collection of illustrative statistical information of every branch and kind. This was the view of the subject taken by Sir W. Petty, although he was unable to realise his wishes in respect to the latter portion of the enquiry to their full extent, and such was the enlightened view of the true objects of a survey with which General Colby commenced the Irish survey, though he too was not permitted to carry out the noble design in its integrity.

The work of survey was in full progress under Mr

Worsley, when Sir William, then Dr., Petty, who had come to Ireland in 1652, as physician to the forces and to the household and family of the Lieut.-General, being a man of extraordinary acuteness of intellect and energy of character, came forward to impeach and condemn the manner in which the survey was then conducted, and to offer to undertake on his own part its completion on sounder principles and in a much shorter time. The acrimonious disputings between Mr. Worsley and Dr. Petty, and the complaints of the surveyors who had been employed by Mr. Worsley, which necessarily followed this bold and startling proposition, do not require to be here detailed, as the Council was at length convinced of the wisdom of Dr. Petty's proposals, and his offer being accepted, the remarkable work called "The Down Survey," from "its topographical details being all laid down by admeasurement on maps," or as "the survey laid down," was the result. In briefly detailing some of the arrangements of the Down Survey, and the civille and grosse survey which preceded it, they will occasionally be compared with corresponding arrangements of the Ordnance Survey, and the justice of the following remarks of Lieut.-Colonel Larcom will be fully appreciated: "Generally, in regard to all, nay, to each and every of them, it is not beside the subject to say that there is not one of these precautions which was not found indispensable in the similar work of the Ordnance survey, and it is even more remarkable that clear directions on the same points

were laid down also in the similar instructions prepared by the able director of that work, Colonel, since General, Colby, who, it is needless to say, had never seen or heard of the archives and documents we are now consulting and printing. Many of the instructions of Dr. Petty and Colonel Colby might be printed in parallel columns, so remarkably have the same circumstances produced the same results, from minds very similar in some respects to each other." Sir W. Petty must, indeed, by any historian of the Ordnance survey of Ireland, be considered its progenitor as a great practical work, just as General Roy was its progenitor as a work of science.

Objects.—The object of the Down survey has been clearly stated; namely, as a basis for the distribution of the forfeited lands amongst the adventurers and soldiers, who had either by money or in person contributed towards the expulsion of the old proprietors and the quelling of the rebellion which had led to the forfeitures. The object of the Ordnance survey was to provide a basis for the equitable adjustment of local taxation. The Committee of the House of Commons of 1824 thus reports: "The surface of Ireland consists of about 20,000,000 acres in English measurement, divided into 4 provinces, 32 counties at large, 8 counties of cities, towns, or other independent local jurisdictions, 252 baronies, about 2,400 parishes, and a further civil subdivision, generally known as townlands, but bearing different names in the several counties in Ireland. These

sub-denominations, which may be generally expressed by the word townland, are the ancient and recognised divisions of the country; they form the basis of the Down survey; they have been long used in the apportionment and collection of country and parochial rates. It is obvious, that if a baronial or even a parochial subdivision were alone to be effected, sufficient data would not be furnished for the apportionment of the local taxes; and if, on the other hand, a survey by fields were to be undertaken, as in France and Bavaria, the expense of such a work would be augmented, and its completion postponed. A survey by townlands appears to your committee to be the rational medium between these two extremes; sufficiently close for practical purposes, without aiming at any extreme minuteness of detail." The Down survey, for many years had been unfitted to supply the wants of the public in respect to taxation. In its original state it consisted of 31 folio volumes of survey maps of lands forfeited by the rebellion of 1641. The respective baronies on a small scale, including as well as they could the denominations of lands therein; and upon a more useful and extensive scale, the various denominations contained in the space of the respective parishes, a folio sheet being added to each parish, describing its site, bounds, particular denominations, content, forfeiter's names. Of these volumes, many were nearly and some totally destroyed by a fire, which took place in 1711; and though it was proposed to supply the deficiency thus created by a copy made by General

Vallancey of a set of the maps which Sir W. Petty had copied for his own use from the originals, and which, having been captured by a French privateer when on their passage to England, had been lodged in the King's library at Paris, the Parliament had never ventured to give legality to this copy, which only extended to the baronial maps, even as evidence of boundaries; Mr. Handcocke remarking in his evidence that "General Vallancey's copy is a transcript of the copy of the original baronial maps only, defective of every other likeness or means of information, too minute in many instances to afford the strong contour by which original boundaries, if defaced by time, could be accurately defined; too confined sometimes in space to declare the quantity, or ascertain landmarks, such as castles, churches, &c., &c.; in some instances and very many indeed, erroneous and differing from the originals as to figure, but totally deficient as to every other source of information afforded by the originals. To authenticate them generally and entirely as records, might be dangerous; partially, where the originals have been destroyed, some use may be safely made of them; but, in no instances should they be admitted to serve as proofs on trials of boundaries, unless where none of the originals can be had." And if, defective, from its now imperfect condition, even as an indicator of territorial boundaries, how much more so must it have been as a guide to the determination of the quantity and value of land, when it is remembered that though a great, nay, a

wonderful work, for the period of its execution, and from the extraordinary fact that it had been completed in about two years, it was not founded upon a scientific basis, nor calculated to represent the altered condition of the country after the lapse of nearly two centuries, nor to meet the exigencies of an improved agricultural and social system.

To supply at least some of that information necessary for an equitable adjustment of local burthens which could no longer be derived from the Down survey, several county maps had been constructed on various scales and of very different degrees of merit, but as such works could not be achieved as parts of one great whole, and therefore be stamped as legal documents of reference by one uniform authority, they were of little or no influence in abating the evil complained of, and in consequence the various assessments were made in the most irregular manner, sometimes from old county books or keys which were arranged when the relative value of the land was quite different, and sometimes in a still more loose and arbitrary manner. In the county of Limerick the whole assessment upon the county was first divided amongst the baronies, proportionably to the number of acres in each, but without reference to the comparative value of the land, and this principle was again followed in apportioning the baronial assessment amongst the townlands, so that the rate levied when estimated in proportion to the actual annual value or return of the land, was ruinously unequal, 100 acres of the most inferior

land paying as much as 100 of the very best. In the county of Waterford, the Treasurer, Edward Roberts, Esq., stated, that "The county is divided into 489½ ploughlands, of which each barony contains a different number; for instance, the Barony of Glanaheiry 14, and that of Decies without 122; so that if £10,000 be presented on the county at large, that sum is divided by 489½, and each barony bears its proportion according to the number of ploughlands therein. Here it will be observed, that though the tax on the ploughland itself was collected by the acre, the allotment was made without any reference to the number of acres in the townland, or to their value, a custom, as Mr. Roberts remarks, "fraught with much injustice; for instance, there is in the Barony of Coshmore, one ploughland, containing upwards of 8000 acres of which 2000 are arable land, and another ploughland, which contains only 180 acres, and both these ploughlands bear an equal share of the tax charged on the barony." In the county of Wexford the treasurer stated, "There is no general scale followed by the baronial collectors for apportioning the cess on the several sub-denominations within their baronies, as *each barony* has a *different modus* of ascertaining the same from custom, time immemorial." Mr. Daniel Mussenden stated that "they applied differently in different baronies in the same county; they applied by the townland in my neighbourhood in two baronies I am concerned in. The townlands are very unequal in size; they probably were of the same value when that

division of the country was made, of which we know nothing; but from the improvements of the county they are now very unequal." Even where the Down survey had been adhered to, as in Tipperary, it had failed to secure equitable adjustment, as it had originally only professed to make the one great general distinction between profitable and unprofitable land, and therefore was no longer a fair representation of the relative capabilities of the land to support taxation. A magistrate of the county, Thomas Lanigan, Esq., stated, "The money is levied by a very erroneous and unfair mode of calculating the taxes by the Down survey. We are supposed to be taxed by the acre, but it is a very unfair survey. I know some persons who do not pay half the taxes they ought, and others who pay much more." Doubtless the unfairness here referred to was not connected with the original accuracy of the survey, but with the great alteration in the relative condition of lands, which must have taken place in so long a time, and were similar in character to that referred to by Mr. Leslie, member for the county of Monaghan, in his evidence. "The applotment is laid on by what we call the townland; the townland differs much in quantity; the applotment was made in the reign of William the Third; it was then regulated according to the value of the land, consequently land at that time not so valuable has since become very valuable, and paid scarcely anything in proportion, so that the tax is now very unequal." Indeed the Right Honourable Denis Browne, afterwards Lord Oran-

more, describes the taxation of Mayo as *ridiculously unequal*, and gives as an example the case of "Mr. Harry King, who has a farm from which he gets no rent, because by some strange jumble the whole tax of a great part of the district is thrown upon it; and there is a large surface of fine land adjoining it, which pays nothing." Such then was the irregularity and injustice of the local taxation on land in Ireland, when the imperial parliament was urged, by its most influential members, to remedy the evil by a general survey and valuation of that country. The great analogy therefore between the Down survey and this newly projected survey is in the fact, that they were both planned for practical objects connected with the land, whilst in other respects, though there were many points of resemblance as to the details of the operation, there were also equally striking features of disagreement: the Down survey being a collection of maps, not capable of being combined into one whole, and the Ordnance survey one great map of the whole country, though for convenience divided into a number of parts; the Down survey, whilst delineating the territorial boundaries, adopting the one great distinction between profitable and unprofitable land, as the only one required for the mere purpose of distributing the forfeited estates amongst soldiers and others, and the Ordnance survey, whilst delineating the boundaries in a similar manner, but with that more scrupulous accuracy which was necessary to render the map a fitting basis for the minute valuation required

in the nineteenth century, by the improved agricultural and commercial condition of the country, applying all the resources of modern science to make it equal as a great topographical work to any survey or map undertaken by any European or other government.

SCALE.—In determining the scale of a map it would appear to be easy to adjust it to the representation of everything intended to be embraced by the survey, either as boundaries or as objects; and yet the example of the Ordnance survey proves how difficult it is to bring all opinions into harmony even upon a matter of such apparent simplicity. For the Down survey, Sir W. Petty adopted the scale of 40 perches to the inch for the first great plot from which the content in acres was to be estimated, and for a large barony plot the scale of 80 perches to the inch, these latter plots being reduced into maps of various scales according to the size, so that each barony might be brought into one sheet of paper. The committee on the Down survey reported (1813) "We find that the existing parts of the Down survey consist of two sets of maps; one set containing a map of each barony into which the several counties are divided, and the other a separate map of each parish. These baronial maps are in general on a scale of 160 perches to an inch, but in some the scale is as small as 320 perches to an inch. The parochial maps existing are in general on a scale of 80, but some on a scale of 40 perches to an inch. From the difference of the

scale on which the baronial and parochial maps are formed, there are in almost all, if not in every one, of the parochial maps, numerous names of denominations of lands, which are not mentioned in the baronial maps of the existing Down survey, the baronial maps noticing only the parishes, and most considerable denominations of the lands." A somewhat similar arrangement was adopted in the Ordnance survey of Ireland, as the index maps of counties are drawn upon scales varying with their magnitude, so as to include the county in one sheet, whilst the general townland map is of one uniform scale throughout. The scale adopted for the Irish Townland survey was 6 inches to the mile, a scale which had been previously tried in the English survey, as was thus stated by General (then Major) Colby, in his evidence before the select committee of 1824; "The English survey commenced upon a scale of six inches to a mile, on which scale the map of Kent was originally plotted, and it is now carried on in the scale of two inches to a mile," and he added in reply to a question, whether such a scale was sufficiently large to represent distinct divisions of land varying in size from 50 to 300 acres, "I should think it would represent those divisions very completely." From this extract it does not appear that General Colby had previously proposed a scale for the Irish survey; but in his reply merely expressed an opinion on a scale then suggested to him by the committee. The evidence of Mr. Richard Griffith, the well-known civil engineer and geologist,

was, however, more positive in its character. The direct question was put to him; "What scale would you propose for the maps that are to be executed by the surveyor for the purpose of valuation?" and his reply was equally explicit, "I should recommend the scale to be six inches to a statute mile, but in the survey of towns or villages, or townlands immediately adjoining, where portions of acres are of great value, I think it would be necessary to lay down the map on a scale of 20 inches to a mile; but these should be considered only as supplemental maps to the others, for every townland should be laid down on the scale of six inches to a mile," so that the adoption of that scale may be fairly ascribed to the confidence justly reposed in Mr. Griffith by the committee, and it may be added that his recommendation of auxiliary maps of towns, &c., on a larger scale, has been also carried into effect. As the value of the Down survey was tested and established by its successful application to the purpose for which it was designed, namely, the distribution of the forfeited lands, so has also the value of the Ordnance survey of Ireland been proved by a similar successful application to the valuation of the land; and in like manner its collateral utility to the engineer and agriculturist has been acknowledged by some of the most able men who have actually tried it, and thereby acquired a right to express an opinion on its merits or its defects. Still however the experience of the Irish map has not served to decide the question as to scale generally, either as regards

England or Scotland, and evidence has been given of the most conflicting kind before successive committees of the House of Commons by men of apparently equal scientific eminence, some of whom have desired no other kind of map than the one so long in progress in England upon the scale of *one* inch to a mile, whilst others have recommended the whole survey to be plotted on the scale of 24 inches to a mile, and the map drawn on a scale of 12 inches to a mile. It is not intended to attempt in this memoir to reconcile these differences of opinion, though Colonel Hall, late superintendent of the survey, and immediate successor to General Colby in that important charge, has suggested the following compromise in his very able report. "The scale most adapted for general engineering and statistical purposes is the six inch; increasing or decreasing this scale diminishes the *general* applicability of the map," and "after a very full consideration of the whole of the purposes for which public maps are now and may be hereafter required, I am decidedly of opinion that the 12-inch is the best scale to be adopted for a general map of all the arable rural districts of the kingdom; villages and towns to be an exceptional scale of 2 feet, 5 feet, and 10 feet to a mile according to the nature of the place." These opinions may not appear quite consistent with each other, but Colonel Hall evidently means that he prefers a six-inch map, if intended only to serve the general objects of engineering and agricultural improve-

ments, and a 12-inch, if intended to supply the place of estate maps. Without doubt every unnecessary increase of the scale is a cause of additional labour, whilst it adds to the difficulty of executing the work; and though this may be indifferent to one who is merely called upon to use detached maps for some specific object, the person who has to superintend the construction of one general map of a country must speedily recognise the difficulty of combining together such a multitude of sheets of paper, each of which embraces a mere minute fragment of the country. Colonel Hall, therefore, whilst maintaining that such large plots are not necessary, recommends that, if prepared, they should at once be placed on copper, as the only mode of securing them from the distortions and changes consequent on hygrometrical causes.

A comparison, however, between the scales of the two great Irish surveys, the Down survey of Sir W. Petty and the Ordnance townland survey, suggests at least some reason for doubting whether the scale adopted for the latter work was really the best for the purpose, and whether it would not have been even wiser to adopt the same scale for the Ordnance map as had been adopted by Sir W. Petty for the Down survey, namely a scale of 40 perches to an inch, or 8 inches to a mile; this scale representing 22 yards or 66 feet by $\frac{1}{10}$ of an inch, and being therefore sufficient to exhibit the minutest building as the $\frac{1}{10}$ could be readily subdivided into 2 and even into 4 parts, whilst the advantage would

have been even greater in respect to the acreage, as a square inch would have represented the $\frac{1}{64}$ part of a mile or 10 acres, and $\frac{1}{10}$ of an inch square of $\frac{1}{10}$ of an acre, a subdivision sufficiently minute for most purposes. The facility of estimating areas which such a scale affords is therefore manifest, and at the same time it puts a survey in relation to the measures always adopted in agricultural operations, the perch and the chain; whilst 24 or 32 inches to a mile might still be adopted as a scale for cities or important towns.

These remarks have hitherto had no reference to the more general question of a proportional scale suitable for all countries; which, however, deserves at least a brief notice, as there cannot be a doubt that the selection of some definite proportion for the more general map of every country, such as the one-inch map in England, would be very convenient by enabling a student to read, as to distances, the map of any country in the measures of his own: and even in the larger maps, where a scale of well-known units must necessarily be adopted, as the readiest way of meeting the wants of the practical man, a proportional scale should also be given, as, for example, a scale of 24 inches to a mile or $\frac{1}{2640}$, 12 inches or $\frac{1}{5280}$, 8 inches or $\frac{1}{7920}$, 6 inches or $\frac{1}{10560}$, 2 inches or $\frac{1}{31680}$, 1 inch or $\frac{1}{63360}$.

In the preceding proportional scales, the fractions are all inconvenient for general application, as they are not resolvable into a finite decimal fraction. For example, the 8-inch scale is represented propor-

tionately by the decimal ·00012626, &c.; the 6-inch by ·0000946969, &c.; the 2-inch by ·0000315656, &c.; the 1-inch by ·00001578282, &c.; the 12-inch by ·000189393, and the 24-inch by ·00037878, &c.: numbers which cannot even be approximately adjusted to a finite decimal proportion, for should the decimal in the 8-inch be assumed to be ·00012, it would represent a unit scale of 7·6 inches to the mile, or 8·24 inches if assumed to be ·00013, neither of which would be attended with the practical advantage of the 8-inch scale in respect to areas in acres: and, again, in the 6-inch, if the approximate decimal ·00009 were adopted it would represent a unit scale of 5·7 inches to the mile, or in the 2-inch, where the approximation would be nearer, ·00003 would represent a scale of 1·9 inch to the mile. If therefore it be deemed indispensable, as it undoubtedly is philosophical, to consider every line in a map as bearing a definite proportion to the distance it represents, the ordinary duodecimal scales have the disadvantage of requiring, in every case, a long multiplication by the denominator of the fraction representing the proportion, in order to reduce the measured line on the map to the measured line on the surface of the earth which it represents. To replace them therefore it has been proposed to adopt a scale of $\frac{1}{2500}$ for rural districts, and $\frac{1}{500}$ for towns, equivalent respectively to scales of 25·34 inches, and 126·72 inches or 10 feet 6·72 inches per mile; these scales being those adopted in France and Belgium, where they are so readily applicable to the decim-

metrical scales of those countries, and being also very easy of application to any form of unit scale, the fraction $\frac{1}{2500}$ being represented by the decimal ·0004, and the fraction $\frac{1}{500}$ by the decimal ·002; so that any distance measured on the map is at once reduced to the true distance in space by multiplying it by 10,000 and dividing the product by 4 on the one scale, or by multiplying by 1,000 and dividing by 2 on the other; as, for example, 5 inches on the map are equal to $\frac{50000}{4} = 12500$ inches, and 2 feet on the other scale are equal to $\frac{2000}{2} = 1{,}000$ feet.

Notwithstanding however the ease with which this proportional scale may be used in estimating distances, some of the most scientific men in the country have differed in opinion as to its advantages and disadvantages. As stated by Professor Piazzi Smyth it is *not* a decimal scale, and therefore not entitled to the prestige attaching to that name. Nor is there any good reason for preferring the French metrical system to a decimal system founded on our own yard, as the metre can only be considered an approximation to a natural standard, and must be practically determined at any time by reference to a standard bar *assumed to be* the $\frac{1}{10000000}$ part of the earth's quadrant, just in the same way as the length of a yard would be determined by reference to a standard bar, stamped as a true yard by authority. For the purposes indeed to which maps on so large a scale as those now under discussion are likely to be applied, there seems little advantage in forcing a uniformity between the maps of other countries and those of our

own, as it is highly improbable that an Englishman would ever find it necessary to consult so large a foreign map, or *vice versa;* but with maps of a smaller scale it would indeed be highly desirable that the same proportional scale should be adopted for all countries.

The one practical disadvantage, that the result is not at once given in measures which convey to the mind a distinct notion of distance, such as 1, 2, 6, 8, 12, &c., inches do, in those scales in which they respectively represent a mile, can be easily obviated by printing, on each sheet of the map, scales, divided according to the received measures of this and some other countries. The Astronomer Royal proposed proportional scales of $\frac{1}{800}$ and $\frac{1}{3000}$ as more available with our measures for the large maps, but the Government has provisionally adopted the scales of $\frac{1}{500}$ and $\frac{1}{2500}$ and so far as distances are concerned the regret will be that a more purely decimal scale could not have been contrived, as it may fairly be asserted that after all, the image of distance conveyed to the mind by the word "mile" is extremely vague, and varies with almost every person, the pedestrian and the equestrian, for example, viewing it under very different aspects. In small scale-maps where estimates of distance are made in reference to the time of journeys, the mile is indeed a useful unit of comparison, but in the large scale maps the objects of reference will far more frequently be connected with feet and yards, or links and chains; and as the great advantage of such maps is, that they are at once adapted to all the purposes of minute registration,

and to all the wants of the farmer, care should be taken to render their use for such purposes as easy as possible. Whatever then may be the result of the present effort to introduce a decimal division in all measures, it is probable that the acre will still continue the unit for land measurement, and if so, some assistance should be given to the farmer in determining at sight his acreage; which might be done by engraving on the large maps vertical and horizontal lines forming by their intersection squares of ten acres. In the scale of 8 inches to the mile, every square inch would thus represent 10 acres; in that of 16 inches, the square of 2 inches; in that of 24, the square of 3 inches; and in that of 32, the square of 4 inches; whilst squares of $\frac{1}{16}$ $\frac{2}{16}$ $\frac{3}{16}$ $\frac{4}{16}$ of an inch would respectively represent $\frac{1}{10}$ of an acre; so that, presuming the squares of ten acres were represented on the map, every farmer would be able to subdivide his land with the utmost ease and precision, and adjust the several portions to the rotation of his crops—the maps thus truly becoming agricultural. The same object would of course be attained on any proportional scale in respect to the ten acres, by engraving the squares, but here the farmer would require to subdivide the lines of the squares into ten parts for subdivision into $\frac{1}{10}$ of an acre, though this might also be done by the engraver at the margin lines of the map.

This important section of the subject may be summed up in the following manner:—

1. *The scale of one inch to a mile* has been found suitable for the purposes of a general map, and more especially so where the surface of the country is marked by strong reliefs, which can be brought out effectively by shading. The feeling of the public is decidedly in favour of the completion of this map for the whole United Kingdom. Viewed as a proportion scale it is inconveniently represented by the fraction $\frac{1}{63360}$, and might be therefore replaced with advantage by a scale of $\frac{1}{60000}$, corresponding to a scale of 1·056 inch, which for ordinary itinerary purposes might be approximately and conveniently read by allowing 20 miles to 21 inches, the error being only one mile in 110. A proportion of $\frac{1}{50000}$ would perhaps be still better, as being at once reducible to the decimal ·00002: it corresponds to 1·267 inch or nearly $1\frac{1}{4}$ inch per mile, so that every 5 inches would correspond to 4 miles, or 20 miles to 25 inches, the error being about one mile in 80, and is, therefore, a very desirable scale, independently of its simple relation to the proportion $\frac{1}{2500}$ adopted for the large maps, from which it is derived by multiplication by $\frac{1}{25}$.

2. *The scale of* 6 *inches to a mile* has been found sufficient for all the purposes of the townland survey of Ireland, but it must be remembered that it was intended by General Colby to serve merely as a representation of the data required for valuation and taxation, not as the means of obtaining those data; and in consequence that it exhibits the area of the townlands as obtained by direct calculation from the

distances measured on the ground and not from paper measurements. Even in respect to boundaries, as will be seen hereafter, General Colby introduced a written description of them, resembling what was formerly called a survey, in contradistinction to a map, and which would materially assist in clearing up difficulties or settling disputes. The Committee of the House of Commons of 1824 expressly excluded from their consideration the question of estate or property maps, and there can be little doubt, therefore, that the scale adopted was a judicious selection for the objects it was intended to fulfil. Had General Colby been required to provide for the wants of registration by producing a map on which distances of 4 or 5 feet might be determined by paper measurement, and to supply to the proprietor or farmer detached property maps, he would unquestionably have selected a larger scale; but as the case stood he adopted a moderate scale for portability's sake, marked upon the maps the areas with the utmost possible precision, preserved accurate written descriptions or records of the boundaries, and added to the maps a large amount of collateral information in altitudes, which had never been before contemplated. Whatever therefore may be said by civil engineers or surveyors of the superior advantages to them of larger maps, to General Colby must be awarded the honour of first endeavouring to make the great national map available for all such practical purposes. The nearest convenient proportional scale would be $\frac{1}{10000}$, corresponding to 6·336 inches per mile.

3. *The 8-inch scale*, as well as its multiples, 16, 24, &c., is admirably suited to land measurement, 1 inch, 2 inches, 3 inches square representing ten acres, and $\frac{1}{10}$ $\frac{2}{10}$ $\frac{3}{10}$ of an inch square $\frac{1}{10}$ of an acre. It was the scale of the Down Survey.

4. *A scale of* 3 *chains to the inch*, or $26\frac{2}{3}$ inches to the mile has been advocated by several of the surveyors as being in frequent use with them; but with respect to the measurement of land or determination of acreage, the scale of 4 chains to the inch or 20 inches to the mile, or 5 chains to the inch, or 16 inches to the mile, appears preferable; a square inch on the first representing 1·6 acre, and on the second $2\frac{1}{2}$ acres.

5. *The proportional scale of* $\frac{1}{2500}$ has the advantage that a square inch is so nearly equal to one acre, that it may be practically assumed to be equal.

6. Mr. James Saunders has proposed a scale of 28·8 inches to the mile, in connection with a decimal division founded on the yard as a unit. In this system the yard would be divided into 100 parts or chains, and each chain into 100 links, the proportion being $\frac{1}{2500}$, so that 22 chains in the field would be equal to one link on the paper, and one square yard on the paper to 1,000 acres. As the yard is the only standard measure of England, it seems only reasonable that it should be made the basis of any future decimal system of measures, and this mode of dividing it into 10, 100, 1,000 parts has also much in its favour as regards the measurement of land.

7. Finally, it may be said, that if a proportional

scale be desirable for very large scale maps, which can rarely have any but a very local application, it is far more so for small scale maps; in the one case there can be rarely any necessity for the comparison of distant localities, in the other such comparisons may be frequently necessary. In the small scale map the unit of comparison will be large, as the mile, the kilometre, the werst, &c.; whilst in the large scale map, the unit will be some familiar measure of less extent, such as the chain or the perch; and as the persons who use such large scale maps, for agricultural and other purposes, are not generally acquainted with the theory of proportional scales, it is desirable to assist them not only by engraved scales, but also by the system here recommended of ten acre squares, each side of which would be equal to 10 chains, and therefore at once suggest to the person using the map a convenient and well-known unit of comparison.

Mode of Determining Boundaries.—*In the Down Survey* this very important operation was confided to the director of the survey, Dr. Petty, who was required by his instructions, "to have if possible such bounders as shall be recommended by the jury that gave information to the Commissioners of Civil Survey causing them to be either sworn, or subscribe before good witness, unto the truth of the bounds they shall shew unto you. Where the meares are not certainly known, but two are offered as likely to be them, then you will take notice of both, viz., of the most likely by admeasurement,

and of the other by estimate, making extraordinary marks at all such places, and recommending them to the country, and expressing the controversy about the said meares in your respective returns."

In the *Ordnance Survey* the responsibility of determining the townland boundaries was even greater, as they had become, almost universally, the boundaries of property, and the value of that property had so greatly increased; nor was the difficulty to be expected chiefly in well-cultivated and valuable districts, as it may be presumed that such boundaries had been constantly kept in view and were therefore easy of recognition, but rather in the wilder and mountainous districts where the boundaries had been preserved more by tradition than practical knowledge, and where, of course, the appeal would be answered differently by different parties. The writer of this Memoir was, for example, waited upon by the agent of a great proprietor, with the intention of convincing him that his employer was right in claiming a portion of a barren mountain summit, whilst his adversary declared that it was on his side of the boundary; and the agent appeared much disappointed on finding that the Ordnance officers were to be engaged in the actual survey of the boundaries when determined, and not in discovering or determining them. Military men were indeed little fitted for entering into such disputes and Major Colby was therefore most wisely disinclined to undertake this part of the work which was confided to a special boundary department

ancient names by stating that the "barbarous and uncouth names of places" in Ireland much retard the reformation of the country, and directing "the Lord Lieutenant and council to change such names into others more suitable to the English tongue, annexing the ancient names in every grant so altered." These directions were embodied in the acts of explanation, but we may well sympathise with Lieut.-Colonel Larcom when he observes that, "few persons will now be found to regret that the change of names thus authorized and ordered was not generally carried into effect." In the *Ordnance Survey* the importance of a correct determination of names was felt and fully appreciated, and "Name Books" were established by Major Colby, in which the officers entered the names, according to the best information they could acquire; but the enquiry did not rest here, but became the subject of the most careful antiquarian research. Lieut.-Colonel Larcom, who took so active a part in this and other branches of the survey, observes in respect to names, that, "as for the orthography of the names engraved on the maps of the Ordnance Survey, the different spellings and alias names of every townland were collected from all accessible documents, some (where the names were ancient) of very great antiquity; and finally, local inquiry and examination were made by an Irish scholar on the spot, to render the name ultimately adopted as nearly as possible consistent with the ancient orthography. This information being all classified, and arranged in proper descrip-

now substituted for the approximate data of the Boundary Note Book, and it may be fairly said that this book is a document of the highest importance, as it will afford at any future period the means of tracing out the boundaries, even should the natural evidences of them, such as fences or streams of water, &c., have either been removed or have altered their courses. This description of written survey is quite in conformity with the practice of the Down and other ancient surveys, and in many cases would prove the only mode of arriving at truth, as for an example, in the case of a question as to which side of a fence had been the boundary—and the establishment of such checks and records must be considered a striking example of the forethought with which Major Colby entered upon the organization of a survey, so widely different in its requirements, from any of the surveys with which he was then acquainted.

NAMES.—*In the Down Survey* it was expressly declared by an ordinance of the Protector's Council, that "all counties, baronies, and places returned or certified in or by, miswritten, or wrong names, shall be enjoyed by those whose lots are or shall be on such counties, baronies, or places, as if they had been returned or certified by their true and proper names; and Lieut.-Colonel Larcom quotes from the records then in the custody of the late Sir William Betham, a memorandum of an order from King Charles, which goes beyond this tacit recognition of carelessness, and enjoins the corruption or change of the

ancient names by stating that the "barbarous and uncouth names of places" in Ireland much retard the reformation of the country, and directing "the Lord Lieutenant and council to change such names into others more suitable to the English tongue, annexing the ancient names in every grant so altered." These directions were embodied in the acts of explanation, but we may well sympathise with Lieut.-Colonel Larcom when he observes that, "few persons will now be found to regret that the change of names thus authorized and ordered was not generally carried into effect." In the *Ordnance Survey* the importance of a correct determination of names was felt and fully appreciated, and "Name Books" were established by Major Colby, in which the officers entered the names, according to the best information they could acquire; but the enquiry did not rest here, but became the subject of the most careful antiquarian research. Lieut.-Colonel Larcom, who took so active a part in this and other branches of the survey, observes in respect to names, that, "as for the orthography of the names engraved on the maps of the Ordnance Survey, the different spellings and alias names of every townland were collected from all accessible documents, some (where the names were ancient) of very great antiquity; and finally, local inquiry and examination were made by an Irish scholar on the spot, to render the name ultimately adopted as nearly as possible consistent with the ancient orthography. This information being all classified, and arranged in proper descrip-

tive books forms a large collection of documents, which, being preserved with the records of the survey, may be at any time referred to or published; and as there is scarcely any more fertile source of confusion than uncertainty of nomenclature, it may be hoped that as the boundaries of the Ordnance Survey are recognized by several Acts of Parliament, the names now engraved on the authorized maps of that survey, may also become generally adopted in all legal and authentic papers." Had the Survey Memoir, commenced with so much promise in the Memoir of Templemore, been extended to the whole country, these names would, without doubt, have been published in connection with their meanings as interpreted by Dr. Donovan, and have shed much light on the earlier history of the country. Accustomed, indeed, as we are, to the use of names which have, during the lapse of ages, gradually undergone so many changes as to have lost all resemblance to their originals, we are too apt to undervalue the importance of clearing away the disguise and tracing out the real and graphic name which lies beneath it, and is in itself a record of some local peculiarity or some historic fact. General Colby was no antiquarian, and the attention he directed to this special object is therefore a strong example of the sound good sense and judgment he exhibited even in subjects to which he had not previously directed his attention.

Mode of Surveying.—In the early surveys the system was that of "simple surrounds," as it was

called, the perimeter of the ground being measured by a chain, aided by the compass or circumferentor, and the area being determined by measuring the figure of the ground, when plotted on paper. Such a system could afford no check against the errors so likely to occur in measuring the perimeter, as the work might close pretty well at the end and yet be affected by many intermediate though compensating errors. In the 11th Article therefore of the instructions issued by Dr. Petty to his surveyors, he enjoined them, "by intersections, to determine the true places of all townes, churches, castles, knowne houses, hills, raths, &c., within each respective surround, and to be frequent in making such observations, for the better examining and correcting your works;" and thus a system of checks was introduced to guard against the possible distortions of the measured perimeter. In the 5th Article of his additional instructions, Dr. Petty provided even for a check upon the truthfulness of the Field Books, as he directs, "as to the trueth of the field books, you shall, as often as you see occasion, cause some angles or sides, or both, to be measured (unknowne to the measurer unto whome the measuring thereoff is allotted), thereby to examine any sophistication of the said field books;" and in the 6th, he directs that "the common lines of each barrony are to be run together by two distinct measurers at once, their respective servants keeping double reckoning of the chains alsoe;" whilst in the 7th he explains the mode of applying the checks in plotting; thus,

"As often as conveniently you can, you shall protract your large surrounds before you doe the inworke of the same; neither shall you allow of such inward lines as you have taken by intersection from the outmeares, untill the said outmeares bee approved of by protraction; and when you shall correct any worke by tyeing lines, you are to select and run for that purpose such lines as may alsoe subdivide the said great denomination into its several properties and qualities, according to the rule aforegiven."

These instructions manifest a great improvement in the mode of survey, as compared with the "surrounds," which had been before used without any system of cross or traverse checking. In the Ordnance Survey, "surrounds" when necessary for the measurement of roads, &c., became secondary, and dependent on the internal triangulation, as in this work a complete and regular triangulation was established, from the great triangles depending upon and proceeding from a base line measured, as will be hereafter shown, with all the precision of modern science, down, through various gradations, to the minor triangles, the sides of which were required to be measured with the chain. In such a system as this all must depend upon the fidelity with which the field work has been executed and recorded; and the most effectual mode to ensure such fidelity, was to separate the duty of calculating, and of protracting the angles and lines, from that of observing and measuring—the one devolving on the field parties, and the other on the office computers and draught-

men. Some misconception seems to exist in the minds of surveyors as to the advantage of this division of labour; which, indeed, they have looked upon as derogatory to their profession, inasmuch as it degrades, in their estimation, a surveyor to the rank of a mere mechanic. In such cases the ordinary pride of man being enlisted against the judgment of a man of science, has, as might have been expected, produced many partial and much exaggerated opinions, the error of which becomes apparent on the very slightest examination. Beginning, then, with the great triangulation, it is evident that the field observer can seldom do more, in the way of calculation, than roughly work up the data of the few triangles he requires for protracting his own general diagram. He sends then his observation book, with a diagram explanatory of the approximate positions of the objects, to the computer, and if the latter experience any difficulty in making use of either of these documents, the fault must be ascribed to the observer, who has either wrongly exhibited the objects on his diagram, or has made mistakes in observing or recording their angular positions. To every one accustomed to the observation of distant terrestrial objects, the difficulty of recognising with certainty every member of a cluster of mountains, of which the relative positions change in respect to every observing station, must be familiar; and though this difficulty may be greatly diminished by a point-fixer furnishing the observer with a rough diagram of all the objects of importance surround-

ing the station he is erecting, and marking upon it when possible, the lines of direction to the several observing stations, there must occasionally occur misnomers which the calculator and protractor will as readily detect, as the observer would have done, had he been also the calculator. The advantage indeed of being able to proceed simultaneously with observations and calculations, and thus to detect errors or to suggest deficiencies, at the earliest possible moment, is so great, that no one acquainted with the practical working of the Ordnance Survey will doubt the wisdom of separating the office of calculation from that of the observer. In the minor triangulation the necessity of such an arrangement was still more manifest, as the increased number of observers would have led to great confusion, had it been attempted to carry out the calculations individually. When the survey commenced in Ireland, a district arrangement was established; each district, five in number, being placed under a captain, under whose direction it was intended that the district triangulation should be conducted, whilst the divisional, a still minor triangulation, was entrusted to the lieutenants acting under him. There was thus a gradation of work, as of instruments, the primary distances determined by the work of the great theodolite of Ramsden, or in immediate connection with it, being furnished to the district captain by the officer conducting the primary triangulation, and the divisional officers being supplied with their initial distances, determined by the observation of

12-inch theodolites, mounted on Bond's repeating tables, by the district captain; when the divisional officer proceeded to perfect his minor triangulation, as the true basis for the chain measurement, by observations made with 7 and 8-inch theodolites.

For some time this system was adhered to, but it soon became evident that as each officer framed his triangulation in reference solely to his own wants, the junction work, common to two districts, often became intricate and confused; and this was even more strikingly the case with the altitudes of common points, when determined by independent observers working from opposite directions, and from distinct data. In 1833, therefore, Colonel Colby determined that the secondary triangulation should be conducted as one whole, and intrusted to the writer of this memoir the task of forming and superintending a department for that purpose, the completion of the great triangulation having left him disposable for this new service. To effect such a change at a time when the district surveys were beginning to advance with considerable rapidity, involving, as it did, the creation and training of a corps of observers, was a task of considerable difficulty and anxiety, giving rise at first to many complaints on the part of the district and division officers; but all difficulties were soon overcome, and as the number of observers increased, the demand upon them increased also, as it became a race between the two branches of the work, the triangulation department struggling to anticipate the wants

of the districts, and the districts to run ahead of the triangulation,—whilst the rivalry, amicable though it was, consequent on their separation, rendered each department a check upon the working of the other. In a very few years, the triangulation department was able to supply data in distances and altitudes for the chain survey of three or four millions of acres per annum, the division officers interpolating such additional triangles from their own observations, as might be found necessary to check the chain lines connected with internal or townland boundaries, or to complete the content survey. The calculation of so large an amount of work, produced from the simultaneous observations of 30 or 40 observers, could only be carried on successfully by a well-organized body of computers, for here at least no one could doubt the impossibility of connecting calculation with observations, and this object was attained by the establishment of a second computing office, in the country, in addition to that already existing in Dublin, so that it might be moved occasionally and kept as central to the field work as possible. Simple as these arrangements now appear, the establishment of such a system, at a time when every moment was in itself precious and the chance of retarding a work on the progress of which public opinion had been much awakened and expressed was at least a formidable risk to undertake, may be taken as another example of that firmness of character which so much distinguished General Colby. and which rendered him philosophically calm amid-

clamour, however loudly, or censure, however unfeelingly expressed, so long as his judgment was satisfied as to the wisdom of his plans and the rectitude of his determination.

For the actual content survey, measurement by the chain closed the graduated series of operations, checking, and being checked by, the minor triangulation, and affording the materials for calculating the area of the townlands. In this respect, the difference between the Down and Ordnance Surveys is very great, as the former, like some modern surveys, depended for its areas on measurements from paper, whilst in the Ordnance Survey of Ireland, the actual measured lines were entered in calculation books, framed on a prescribed form, and thus used directly for the determination of acreage. This feature of the survey does not appear to have attracted the notice it deserves, in the many discussions which have since taken place as to the proper scale of surveys for valuation, or other practical purposes. When the survey was first commenced, many schemes were proposed for calculating the area, some depending on measurements, either from the paper itself or from a trace previously taken on glass graduated into squares, and some on the principle of substituting weighing for measuring, by tracing the boundaries on thin lead plates rolled of a definite thickness, so as to give a certain proportion between the weight and number of acres. Ingenious as some of these plans were, they would have introduced into the determination of acreage; first, the chances

of error consequent, in protraction, on changing the natural scale of measurement in the field into the artificial scale of the map; secondly, the probable errors of measuring lines on paper; and thirdly, as r ırds weighing, the errors which must have at- the use of plates of metal from the in- (iti of thickness, which however minute, must e n erially affected the accuracy of the results. t Colby therefore determined to obtain the reage from the lines actually measured on the ground, and thereby to reduce the possible error in amount to a comparatively minute quantity de- ıding on the possible error of chain measure- s. By this arrangement, the maps on the : ıch scale have become practically useful to prietors and farmers, to an extent which only who have used them can fully appreciate; and reason of this is evident, as the acreage marked (every townland, being determined with almost lute accuracy, the subdivision of the townland for f ning purposes only requires the proportional di ɔn of a known and certain quantity of acres, l is liable only to error in determining that pro- po on; as, for example, suppose a townland divided to ıares of any convenient size, or covered by a ı ɜo divided, it would be only necessary to com- e the number of squares occupied or covered by y field or substance with the total number of es occupied by the whole townland, in order at ɔe by a simple operation to ascertain the acreage the field. If, in the six inch map, the square of

the glass or other transparent measuring plate be made $\frac{1}{100}$ of an inch, it would represent on that scale about ·18 of an acre, and it may therefore be readily understood how accurately the acreage of the subdivisions may be determined; the acreage of the whole having been previously given, as a quantity practically free from error.

When the Irish survey was first projected, a valuation of the land, with a view to the more just allocation of taxation, was the main or rather its sole object, and for this purpose alone an engraved and published map would not have been necessary, as a few copies of the plots of the survey might have sufficed for the wants of the valuations. General Colby however, not only foresaw the inconvenience of such a narrow system, as it would then have been impossible that every farmer should check, if he thought fit, the accuracy of assessments made upon him, but he also anticipated the great advantages which would result from the use of such a map for agricultural, engineering, and many other purposes, and he therefore, though still looking forward to the extension to Ireland of the one inch map, successfully urged the publication of the 6 inch map, so that he must always be remembered as the author of the first great practical national map in this country.

ALTITUDES.—The 13th article of Sir W. Petty's instructions refers to this important subject, in these words: "You shall measure the height of all notoriouse high hills and mountains, describing their feet and manner of rising, together with their name

and true places." This was as much as could have been expected, at the time of the Down survey, and little more had been done in the British survey than the determination of the heights of the principal mountain or hill stations; but in the Irish survey, General Colby introduced a new system, by spreading altitudes over the whole face of the map, as well on low as on high ground. For this purpose, the principal stations were fixed in altitude with great precision, partly by direct observation to referring objects at once close to them and the sea, and partly by levelling from the sea line to the referring objects. From the principal stations the heights of secondary points, either hill stations, church towers, or other easily recognizable objects were then deduced; and these, in turn, became initial points for the districts and divisions. Finally, the measurement of the chain lines between stations, the altitudes of which had been determined by triangulation, afforded the means of fixing the levels of a vast number of intermediate points, and thus of placing, at every step, a known altitude mark within a convenient distance for reference. The "Field Levelling Book," and the corresponding calculation books provided for the calculation and record of these subsidiary altitudes in a systematic form, and a comparison of the results from the two trigonometrical altitudes, on which they were based, afforded a check upon their accuracy. Perhaps no published maps have ever been supplied so copiously with altitudes, determined in such a manner as to be practically useful for farming and

engineering purposes, and many able judges have acknowledged the assistance they have derived from them. In considering this subject, however, it is right to remember that the success of the system depends on the accuracy of the primary initial altitudes, and on the mode of deducing the secondary and other altitudes from them; so that it becomes interesting to trace out the steps by which the altitudes of the Irish survey have been brought to their present high degree of accuracy.

In Great Britain, as before observed, the height of certain hills, or other stations near the sea, were determined partly by angles of elevation and depression, and partly by levelling from the low water mark of spring tides. These altitudes were then used for obtaining others, either by reciprocal observations, using two stations, or simply by elevation or depressions from one station only. Such observations required, of course, two corrections, namely, that for curvature and that for refraction, the one constant and certain, the other variable and uncertain. From several reciprocal observations in England, it had been concluded that the refraction was about $\frac{1}{12}$ of the arcal distance between the objects, and this amount of refraction therefore was adopted and constantly used in correcting observations for elevation or depression. In the first instance, the same correction was applied to the observations of the Divis mountain, near Belfast, which was the first great observing station of the Irish survey, and the first primary initial altitude, and many secondary

altitudes, such as the bands or other distinguishing marks of Antrim and other church towers. Supposing the instrument supplied with adequate means for taking the angles of elevation and depression, the value of the resulting altitudes would necessarily depend on the unchangeableness of the proportional correction for refraction, and on the accuracy of the horizontal distances to be used in calculation. In respect to the distances, their accuracy was certain to be far within the limits of required accuracy; but as regards the correction for refraction, the same certainty could not be expected, and in proportion as it deviated from the assumed ratio of $\frac{1}{12}$ of the arcal distance, so would the calculated diverge from the true altitudes, the difference increasing as the distance increased from the observing station. Hence, as a natural result, there was often a difference of 5 or 6 feet in the amount of error of secondary stations, and in consequence the common points of adjoining districts were found to differ widely in altitude from each other, when determined from independent secondary stations, the altitudes of which had been supplied from the great triangulation. This inadequacy of the system of the British survey for determining altitudes with the precision required in a practical work, was almost immediately discovered, in consequence of a comparison of the reciprocal observations of Divis, taken by General Colby, and of Knocklayd, also in Antrim, taken by the author, when it was found that a refraction not of $\frac{1}{12}$th, but of $\frac{1}{14}$ was required to harmonize the results of the

two sets of observations when used seperately; and as this amount was subject to very great variation, sometimes approximating to $\frac{1}{12}$ and sometimes approaching $\frac{1}{16}$ a system of standard heights was introduced so as to get rid of the errors due to uncertain refraction.

In this system, the altitudes of points near the sea in various directions were determined with precision, and these were used as points of reference; the refraction at the observing station being deduced from the known heights of the observing and observed stations, as it was necessarily equal to the difference between the observed angle of depression or elevation, and the angle which would actually give the known difference of altitude between the two stations. The refraction thus obtained was used in determining the altitudes of any other stations nearly in the same direction; and so on with other standard heights, as it was found that the amount of refraction was not constant in all directions at the same time, being much affected by local circumstances. It was not, however, always possible to have a standard point of altitude in the required direction, and hence, notwithstanding the improvement in the altitudes effected by this simple arrangement, it became necessary to abandon the determination of altitudes by observations from distant stations, and to restrain the limits of observation, even by the great theodolite, to distances of about 40 miles as the maximum; and the necessity of such limitations in respect to distance, may be judged

from the following simple illustration. From the station of Culeagh, the Mayo mountains were visible over the intervening Leitrim ridge, and the double peak of a small mountain was a very remarkable object. Now, from the peculiarity of its form, this mountain might be observed, according to the refraction, sometimes as a single conical peak, and sometimes as having two peaks, one being higher than the other, whilst on other occasions it was cut off entirely from the observer's station by the intervening ridge. Another system was therefore adopted: initial bases of altitude were fixed with great care along the eastern and western shores, and observing points were selected, running in lines directly from the one side of the island to the other. These points were distant from each other from 8 to 10 miles, and reciprocal observations were taken between each successive pair; but as a further check, a subsidiary station was selected between each pair of the observing stations, and was observed from the stations east and west of it. By this arrangement, the difference of altitude deduced from the reciprocal observations of the observing stations, which might have been affected by some change in the amount of refraction of one or the other, was brought into comparison with the same difference as deduced from observations made to the intermediate or subsidiary station which being comparatively so near to each of the pair of stations, would be very little affected by any small variation in the refractions. The first line of altitude observations of this

description, was adopted by the author to connect the heights of the Antrim and Londonderry surveys, and to reduce the junction points of adjacent districts to harmony. It ran obliquely from the eastern coast of Antrim to the northern coast of Derry, and was most effectual in giving to the altitudes of those counties a high degree of accuracy, although the observations were taken with an instrument of less size, and very difficult of manipulation. The author afterwards carried several similar lines across the country, using the great theodolite as the observing instrument; and it may fairly be said that the altitudes were excellent, although affected by the error consequent on the use of the low water line of spring tides as the zero of altitude. This had been the referring line in the British survey, but General Colby, who had encouraged every step taken to improve the altitudes, readily abandoned it for the more correct mean tidal line, and perfected the survey altitudes, by having other lines of altitudes determined by careful levelling with the spirit level. In every survey, these two modes should be used in conjunction with each other, lines of initial altitudes being first determined by the spirit level, and these lines connected together by traversing lines of altitudes, determined in the way which has been explained.

The primary and secondary altitudes being thus reduced to a uniform standard of accuracy, the subsidiary and chain line altitudes became also safe points of reference for practical operations of drain-

age, of road making, &c.; and it is at this point that some would have had the progress of improvement stop: but General Colby was not blind to the advancement of topographical science on the Continent, and was ready, therefore, to introduce into the British survey and map any of the improvements which had been adopted there. Looking then at the early sheets of the Irish map, the engineer will be struck by the vast amount of data expressed upon them in regard to altitudes, and may also trace, in many cases, the gradual rise of a hill, by following the course of a chain line, and noticing the successive levels marked along it; but in others, he will find it a painful task to unravel the confused web of levels scattered over the map, or to deduce from them any notion of the features of the country. In a map of moderate size, such as the one inch, in England, some description of shading would of course assist in reducing levels to order, or would even supply their place; and to this object General Colby gave much attention at the commencement of the Irish survey, visiting all the mountain chains, and after a careful consideration of the features of the country, ordering a general map to be drawn, so as to afford a graduated scale of shading to be used subsequently in the inch map, the necessity and preparation for which were never absent from his mind. To a map however on so large a scale as the 6-inch, ordinary shading was inapplicable, and General Colby therefore, in the first instance, left the reader of the map dependent solely on the engraved altitudes. In

1837 and 1838, however, the data of the survey were called into practical use, in aid of another great public object, namely, the determination of the best lines of railway for Ireland; as in that country, so often underrated and even contemned in regard to its supposed want of utilitarian habits, the wise example was set to its more confident sister country, of making the railways parts of one general system, and not a set of isolated and disconnected systems. Commissioners were therefore appointed, using the statement of Lieutenant (now Lieutenant-Colonel) Larcom, "in 1837 and 1838, to report on the most advantageous lines for railways in Ireland, and other matters connected therewith: a general map of the kingdom was deemed necessary, and Lieutenant Larcom was entrusted with the preparation of such a map. On this map the various lines of railway proposed by private parties, as well as those recommended by the Commissioners, were to be laid down, and the map was also to be the means of exhibiting, for the first time, the geology of the whole island, by Mr. Griffiths. The Ordnance survey had extended over only one-third of the country, but the triangulation was complete for the whole island. By the aid of this, the principal latitudes and longitudes were computed, and a net work prepared, by which the detail of the Ordnance survey and the various local surveys—some published, many fragmentary and in MS.—were connected. An outline map was thus completed, but, for geological purposes it was also necessary that the mountain ranges and features

of the ground should be delineated. For this purpose, such material as existed was collected and combined, after which persons practised in that branch of topography were despatched to the principal localities—either where the information was most defective, or where the greatest accuracy was required. From the drawings and enlarged sketches of these parties the original work was corrected, and ultimately a map on the scale of 4 miles to the inch was drawn and engraved. It is believed that this was the first general map of any country in Europe, on which the ground was completely delineated as one whole; and as yet it is the only such map of Ireland. Made, as it was, in much haste, and from very imperfect material, its accuracy could be only comparative, being limited, of course, to that which the original material possessed, with such aid from compilation as careful collation and comparison could supply, with the valuable materials of the Ordnance triangulation for its general basis. It was deemed satisfactory, and the Commissioners by a letter, forwarded through the Treasury, to the Master General of the Ordnance, dated 18th March, 1839, acknowledged the assistance it had afforded them."

CONTOURS.—"It was in connection with this map that Lieutenant Larcom was led to consider the importance and the practicability of adopting the continental system of contours, for exhibiting the third co-ordinate of topographic delineation—the altitude. At his instance, experiments were tried, and an officer, Lieutenant Bennett, set apart for

that duty, which, as the outline plans were then considerably advanced, it was proposed, in the first instance, to make the basis of the general map for delineation of ground. The experiment was successful, and the system was at length deliberately adopted; and provided it be not carried into needless details, it will become a most valuable improvement on the former system."

The introduction then by General Colby, on the recommendation of Lieut.-Colonel Larcom, of contour lines on the 6-inch map was a most important improvement, and such still appears to be the opinion of persons practically acquainted with the working of the Irish map; but, like every new invention or proposed improvement, whether referring to a better system of farming or surveying, it has been strongly opposed and condemned by some men of great influence, and of commanding talents in other subjects, though manifestly imperfectly acquainted with the principles of topographical science. It would be impossible to detail, in this memoir, all the arguments urged for or against contours, by the several witnesses examined before the Committees of the House of Commons, but it will be easy to show that whatever may have appeared to be their force, it would indeed be a retrograde movement to abandon this characteristic feature of a national survey and map, which ought to be framed on the opinions of the scientific men of the world, so as to embrace every possible improvement, and not on the partial views of those who think only of their own wants,

and from habit cling to the imperfect modes to which they have been accustomed; as it is still, and ever will be, difficult to convince persons whose minds have not been fully trained, that crude experiments seldom lead to useful results, and that the experience gained with defective instruments can never be urged as an argument against the advantages which an enlightened theory foretells as the consequence of improved systems and instruments. Contour lines are familiarly illustrated by the horizontal traces left by the sea upon the rocks of the coast, on the recession of the tide, and geometrically they are the orthographic projection upon some horizontal plane of comparison, such as the plane of mean tidal altitude, of the successive lines of intersection with the surface of the ground of a plane parallel to the plane of comparison, and raised successively above it, to such intervals of distance as may be determined upon, whether of 10, 20, 30, or more feet. Now, it is probable that every one would admit the advantage of being able to trace out either a line of some definite level from the levels actually marked on the map, or of being able to judge from such levels the amount of fall or rise between any two points; but when the difficulty and labour of poring over the numbers, and searching out those required, are removed by *contour* lines, the additional aid thus afforded is undervalued, and would be rejected; and this arises from the little information on the subject possessed in this country, although in 1818 it was determined by the Bureau

de Cadastre that the general topographical survey of France should be delineated on the plan of contours.

In respect to very large maps, the contours become a substitute for shading; and in small maps they are the proper basis for field sketching and shading, as they at once impress upon the mind, by their inflections, the true forms of the ground, and powerfully correct the errors which are unavoidable in simple sketching, from the constant changes in the intensity and direction of shadows; and from the extreme difficulty in determining the modulations of the surface where there is no marked shadow, or where the shadow falls in the wrong direction. To the eye, however, acquainted with contours, the plan becomes a model, and though shading is a pleasing addition from the pictorial effect it produces, it adds little to the real practical value of the map. It is most unfortunate that the beautiful maps of Wales, engraved from the sketches of Mr. Dawson, have served to support the argument against contours, and in favour of shading alone for hill sketching; although it may be asserted safely, that were even his son Lieut.-Colonel Dawson, so able a pupil of his father, to attempt to reproduce the same maps from his own sketches, he would succeed only as regarded some very striking features, but would assuredly fail in all minor or less marked details. The beauty of a map is, indeed, too often dependent on the skill of the artist, rather than on the fidelity of the surveyor; and it is certain that the only way to

secure accuracy in the representation of a country is to control the artist by the shackles of geometry, and hence that contour lines alone, as geometrical facts, will enable two sketchers to bring out corresponding results in sketching the same countries.

These remarks, of course, apply only to contours determined accurately by instruments, and not to contours put in by the eye, as the latter depart from geometrical precision and partake of the inaccuracy of sketching; though as a general rule, the sketcher should accustom himself to reduce the ground before him mentally into contours, as he will thereby acquire much more correctness of eye in the delineation of its features. It is probable that the introduction of sketched contours into the map has in some degree strengthened the objections of the opponents of the system; for though the effect of shading is produced by the multiplication of the contour lines, it becomes difficult to distinguish the geometrical contours from the others, and equally so, from the general confusion, to use the contour lines for practical purposes. Restricting, however, the contours to those which have been determined instrumentally, and limiting their numbers according to the scale, so that they shall be clearly distinguished, one from the other, they produce a facility in using the maps for agricultural and engineering works, which no amount of simple levels scattered over the surface, nor shading however artistic, can confer upon them.

Notwithstanding, indeed, the great opposition raised against the introduction of this foreign system

into our topography, it may be said that contours have already gained ground in this country, as may be shown, even by the amount of change of opinion exhibited by the two successive Committees of the House of Commons, the first in 1851, recommending absolutely or unconditionally, "That the system of contouring be abandoned." Whereas, the Committee of 1854, report—

1. "That the levels as above described having been provided, contour lines to a certain extent would be an useful addition to a map on the six inch scale, and *well worth* an outlay of five shillings per lineal mile, this being the cost of contouring, as estimated by Captain Gosset, on the assumption that the levels above mentioned have been previously obtained and recorded; these contour lines should be instrumentally traced with accuracy, and the system of interpolating contour lines should be abandoned.

2. "That contour lines selected from those obtained for the large surveys (if of a different colour) would be an useful addition to the one inch map; but on maps of a larger scale, of 24 or 26 inches, they would be inexpedient."

This latter resolution would have been better had it directed that the contour lines should be introduced into the plans, for the one inch, before the hill sketching, as a necessary element for that branch of the work, and not simply added as a supplementary feature. The map of London and its vicinity, contoured by Mr. Mylne, will be exhibited at the Paris exhibition, and prove that a highly intellectual member of that most talented body, the Civil Engi-

neers, has not been backward to recognise the value of contours; and I may add that the Ordnance contoured map of a large country town was actually used by one of that body, to frame his plan and estimate for its sewerage, so that he became a competitor for the premium offered for the best plan, without having ever set his foot within the town. The names I withhold, as the prize had not been adjudged when my friend mentioned the circumstance to me; but one such fact is of more value than many arguments in proving the practical importance of contour lines on maps.

Military Organization.—Sir W. Petty, much to the displeasure of the surveyors of his time, employed the soldiers, who were available for such an object, on his survey, and this drew forth a remonstrance from several of the surveyors, to the effect that Sir W. Petty had, in their absence whilst engaged on the survey, put in his tender for the survey, and then instead of employing these surveyors upon his work, he had declined to hearken to their propositions, "but upon very hard and unreasonable terms, which they could not accept." The surveyors then went on to say, that had the "Doctor had any more new, certaine, and expeditious way of survey than hitherto had been known or practiced, there had been just grounds for our yielding to the Doctor's terms; but, instead thereof, we find him informing the private soldiers, whose labour he may hire at an easier rate, in the ordinary and common method, where it plainly appeares that the Doctor, by his undertaking, hath not out done the sur-

veyors; for, in his proposalls, there is nothing considerable but his time and price. As for the time, we shall make it evidently appear, by undeniable arguments, that the whole worke will be performed by the surveyors now employed by your lordships within the time agreed upon; and for the price, we are content to accept of less than the Doctor hath proposed, not doubting but that we, who have had experience already in the work, shall be better able to perform the same than such who are raw and inexperienced, though taught by the Doctor." But, to this and all the other objections Sir W. Petty replied,

1st. "That he looked upon soldiers only as hardy men, and fitter than most others for the difficulties previously mentioned, that other men of the like qualifications would serve as well; and in fine, that he cared not for using soldiers otherwise; and for many such could be had together without much staying for others. 2ndly. That it was easy to discover whether soldiers would returne false work on purpose, to the injury of the state. 3dly. These men being designed only for field work, could abuse the state only in the length of their chaine, which would alsoe discover itselfe. 4thly. That no soldier could tell where his own, or any friend's of his, lott should fall, nor whether he should at all measure the land that should be his owne or his friends; soe as all the soldiers, and indeed all the other surveyors, must with much art universally combine to justifie any one person."

The employment of soldiers was adopted by

Colby, on far more enlarged principles than
ated by Sir W. Petty, though it is highly
› that the latter was restrained by prudential
from expressing all his reasons for preferring
men, though requiring to be trained for the
› the civil surveyors of his time. General
hought that the habits of order and disci-
quired by soldiers, were very essential ele-
ı the character of men required to work out
ute details of a great work, which could only
lered successful by the most harmonious
›f all its parts. In the survey of Great
he had already exhibited a tendency in this
ı, by much increasing the number of officers
d, and from the first he determined that the
ıtion of the Irish survey should be military.
t him therefore in the control of his officers,
ed Major (now Col. Sir Wm. Reid, Governor
a) as the local superintendent, and applied
ıntjoy House or Barrack, in the Phœnix
› a residence for the Superintendent, and as
for the Survey; he named captains to com-
ıd subalterns to serve in the districts, who
once appointed by the Duke of Wellington
recommendation alone; and he urged suc-
an augmentation of the Sappers and Miners
› the subordinate ranks of the survey force.
ot however as hardy, or even as well disci-
ıen, that he desired to have the Sappers; he
that they should be instructed and well
men, and for this purpose the new com-

panies, raised for the survey, were placed under Lieut. (now Col.) Streatfield, of the Engineers, and carefully instructed at Chatham, under his superintendence, in Practical Geometry and the elementary principles of Surveying. These men proved most important auxiliaries to the survey, as they formed a nucleus around which the less trained country people, including many accustomed to the more simple operations of a survey, could be collected and formed into one well disciplined body. The Sappers were not however useful only as chainmen, or even as observers with the smaller theodolites; but were valuable assistants in the drawing and calculating offices, and were ultimately employed on the triangulation of Scotland, as observers with the great theodolite. They proved also equally skilful observers with the zenith sector, as may be seen by reference to the last published volume of zenith distances of stars, which contains a mass of observations of great interest and value to the survey, most of which were the work of the Sappers. In addition also to these services, extensive as they were, they supplied some excellent engravers to the map department, so that it may be fairly said, that much of the facility of execution and success of the survey must be attributed to the employment of this valuable class of soldiers; and it should also be remembered that, though General Colby followed the example of Sir W. Petty in the use of soldiers, he went far beyond him in his estimate of their utility; and by adopting a judicious preliminary training,

was enabled to avail himself of their services in some of the most difficult and responsible operations of the survey. These two great men thought and acted, as it were, on the same primary idea and plan; but whilst Sir W. Petty saw before him the crude topographical works of the 17th century, and was an improver of that date, General Colby laboured in the 19th, a century of scientific discovery, and endeavoured to give to his work a character of completeness suitable to such an age. It would be easy to follow the parallel further by enumerating the great collateral objects which Sir W. Petty and General Colby had in view, as being of equal importance with the survey itself; but to this point it will be necessary to refer again, in describing the more purely scientific operations of the survey, and it will be therefore enough here to conclude the comparison with the following passage by Lieut.-Colonel Larcom, who, after speaking of the 'briefe account of the most materiall passages relating to the Down survey,' a manuscript preserved in the record branch of the office of paymaster of civil service in Ireland, observes, "It was the good fortune of the Editor, nearly 200 years later, to see similar foresight and arrangements exercised on a far larger scale in another survey of Ireland, by one who possessed many of the qualities which distinguished Sir. W. Petty, and who also succeeded in carrying his great work to a successful close, under circumstances and obstructions, many of which bear a striking analogy to those which the history will show to have attended

the Down survey. This may give the narrative a peculiar value to those who are conversant with the more modern survey, but it will show to all the importance, nay, the necessity of clearly scanning a work as a whole before entering upon it, and that similar circumstances will perhaps, in all ages, produce similar measures, though each be perfectly independent of the others." It is indeed in this latter quality of grasping, as a whole, the minor details as well as the greater results, that General Colby was more especially distinguished in planning his scheme for the survey, and the Author, who passed many hours in freely discussing every arrangement, as it presented itself to the mind of General Colby, and was thrown by him, as it were, freely down as a gauntlet of challenge, can testify to the clearness of his judgment and quickness of his perception in devising a system, which combined in every branch the most careful field entry with an equally careful office record; and which introduced every precaution against error in the field in surveying, and yet checked it at every step by protraction in the office; and in planning and perfecting a map, which at once should maintain a high standing amongst the best topographical works of the age, and be rich in all the elements of practical application.

Office Arrangements.—It will be readily ;ined that a work of such magnitude as the sur- of Ireland upon a six-inch scale could not have undertaken successfully, without such office gements at head quarters as should secure uni-

formity and efficiency of direction in the first place; and in the second, the means of rapidly collating together the materials received from the districts, preparing them for the engraver, and finally engraving them. The organization of the map office at the Tower, though doubtless equal to the demands upon it of a one-inch survey, never extending at any one time over a large space of country and therefore not calling a great number of persons into employment, would have been totally inefficient for such a work as the Irish survey. One of the first objects therefore of General Colby had been to secure a proper building for the proposed office; and when Sir Wm. Reid, after having seen the military organisation completed, left the survey, he placed in charge of the office one who was competent to form and superintend such a system of management as should ensure order, celerity, and certainty of action, and above all, a due subordination in all branches of the work. In making his choice also of such a person, General Colby had to keep in view the collateral objects which were so wisely associated in his mind with the legally prescribed one, namely, the statistical, antiquarian, geological, and natural history surveys of the country, and he therefore exhibited his usual accuracy of judgment when he appointed Lieut. (now Lieut.-Col.) Larcom to the office, for assuredly all those who have visited the survey office, in the Phœnix Park, in the days of its active operations; have gone through its calculating, protracting, engraving, and printing

establishments; have seen the application of the electrotype process to the multiplication of the engraved copper plates; and have relaxed their minds afterwards by a peep into the museum, arranged, it is true, under the direction of another officer, but still indebted for much of its success to Lieut.-Col. Larcom's judgment and taste, must remember that office as a remarkable example of order and efficiency; and those who have not seen the Mountjoy office, may still study it in the survey office at Southampton, of which it was the prototype.

The magnitude and variety of the objects undertaken by this office may be best explained by another quotation from Lieut.-Col. Larcom's statement to the Inspector General of Fortifications as follows: "It would not be possible in any moderate space to describe fully the numerous branches of duty accumulated at the focus of so great a work as the 'General Survey of Ireland,' the first occasion on which a topographical department was formed for the Ordnance. A few officers of Artillery or Engineers, and a separate corps of draftsmen, with other civilians, had been employed on surveys: separate artists had before engraved maps for publication, and much had been combined in the English Map Office at the Tower; but it remained for General Colby, in Ireland, to create a topographic branch of the Engineer department in all its gradations, combining in one body the Astronomical and Geodesic operations; the territorial surveys fo

particular national or public purposes; the general topographic delineation of country; and the engraving, printing and publishing such surveys and delineations, on any scale, or in any manner the particular service might require; and not only to execute such a work in Ireland, but to combine with, and engraft upon it, from time to time, such extensions or modifications, as the wants of the country, or the advance of science or discovery, might require, to keep *au courant* with every branch of knowledge, and embody all which could be made available to the great work, of which several examples will occur in this memorandum. Such also, in regard to Geology and Natural History, was its application under Capt. Portlock, to productive industry, with many similar or cognate pursuits to which the survey has given rise, or for which it has afforded facilities. For such a department no organization before existed, but at the close of the survey of Ireland it had been satisfactorily accomplished, and the Ordnance possessed a topographic corps, which would bear comparison with that of any country in Europe, embracing, in addition to the officers of engineers, three companies of sappers, and a numerous extra body of civilians."

"Of the departments more immediately confided to Lieut. Larcom, the several branches may perhaps be briefly described.

I. The examination of the original plan was divided into the five separate operations connected with the plans. 1st. The plotting, or construction

from the field work. 2nd. The registering of contents or areas. 3rd. The orthography. 4th. The details of drawing, both outline and ornamental. 5th. The figures of altitude.

II. The draftsmen were: 1st. For general service. 2nd. For reducing to the smaller scale for Ordnance and general maps. 3rd. The drawing of those smaller maps, and selecting and inserting the names and details of topography."

III. The computers formed the link of connection between the original plan and the engraving. This department was chiefly devoted to the calculation of the rectangular co-ordinates which fixed the position of the numerous trigonometrical points within each sheet of the townland survey, by which the construction of each sheet became independent of those around it, the triangulation itself being furnished by the general trigonometrical department. This system of projection was admirably devised by Colonel Colby to render the correctness of engraved maps independent of the expansion and contraction of the paper on which the plans were drawn, with similar sources of error from occasional discrepancy in the district triangulations. It was in fact a re-construction of the maps on the copper itself, which it is believed had not been adopted before in any national survey. The better to carry out this project, a new mode of transferring the detail plans themselves to the copper was also devised, viz., by tracing them with a peculiar ink on transparent paper in small portions, and combining these fragments together by aid of the

new network of points. Another advantage resulted from the substitution of this method for the former practice of pencilling the plan and rubbing it on the wax ground; viz., that instead of the thick and indefinite line, caused by the sulphur, with which, in all pencils, the plumbago is mixed, combining rapidly with the copper, the charcoal of the ink remained sharp and definite for any length of time, so that instead of working from hand to hand with each of the engravers, a number of plates could be kept ready prepared for them, and thus the large number of those artists (from 50 to 60) were kept constantly supplied: these three several subdivisions of this work—the computing, the tracing, and the transferring, each of which occupied steadily from 4 to 5 or 6 persons, under one head computer,—being able to provide sheets for the engravers at the same average rate at which the engravers finished and passed them to the printers, viz., two in three days."

"By this department also the meteorological observations were conducted. It was at first hoped that such observations could have been collected from all parts of the country, and methodized and reduced at head quarters. This was not carried out, but observations of the principal instruments were made and recorded at the office itself in an observatory constructed for the purpose. They were conducted with regularity through the whole length of a Julian period, and it is hoped when published they may yet prove an useful addition to that branch of science, more especially as regards the dew point and tension of

vapour, in respect to which will probably be found the greatest peculiarity of the Irish climate."

"IV. The engraving of so extensive a survey was also without precedent, and required correspondent changes in the system and arrangements of that branch. In this, as in the original plans, it was no longer a question of making a single engraving; it was necessary to divide the operation into its processes, and provide or train a sufficient number of persons possessing skill or qualification required for each. Independently of the rapidity which would thus be gained, it was evident there was no other way in which uniformity could be attained over some two thousand plates, to which number it was probable the whole work would extend. Already it has been stated that the transfer to the copper, which is usually the work of the engraver himself, had been provided for in the previous branch. Great facility, as well as correctness, was soon found to result from this. The great divisions of map engraving, viz., outline, writing, and ornament, were next subdivided, and mechanical aid introduced into every part which was susceptible of it. The difference between cultivated and barren ground was expressed by a rolling machine instead of by hand, the numerous figures of altitude, and trees of particular classes were inserted by punches, instead of being separately engraved. The like application of machinery produced a very beautiful mode of representing the sand, beach, and water, which before were the work of separate and highly paid artists. Ultimately, a number, averaging

sixty, of engravers were daily at work, the whole body being regulated with the precision of a machine, rather than of a body composed of many individuals possessed, in various degrees, of artistic skill, and the result was perfectly successful."

"In connection with the engraving, it would be improper to omit the early introduction of electrotype, which within a few months of its first discovery was made available for the purposes of the survey. It was apprehended that the early plates must sooner or later begin to exhibit the effects of the immense number of maps printed from them, and to guard against such effects, more especially on the more complicated and expensive plates, matrices were taken from them, preserving all the freshness of the original, for the creation of as many duplicate plates as might be at any time required. There was much difficulty in this from the great size of the plates, and this was first overcome on the survey. The practice has now become common, but it is nowhere better done, even at this day, than by the apparatus of the survey office. From the manipulations and experiments of Mr. Dalgleish in the laboratory, it there took the form of manufacture in immense vats of acid, containing fifteen hundred gallons each, with proportionate magnitude in the rest of the apparatus. Other applications of this beautiful science to the purposes of the survey soon occurred, such as obtaining great facility and economy in insertion of corrections or revisions in the plates by merely taking a matrix, and erasing the parts which it was desired

to replace, from it, instead of from the original plate. This has been explained in a Paper by Lieut.-Col. Larcom, in the 'Aide Memoire,' and need not be further adverted to here."

"V. The printing of the maps from the copper plates, was at first an expensive operation. A single printer was employed, on the terms usually paid in private establishments; *i.e.* he was paid so much for every impression printed, all ink, paper, and materials being provided for him. The price paid to him was ninepence for each impression; but when the system of examination, computing, and engraving, was matured, and the progress of the survey in the country had attained rapidity, this price became enormous, and it was resolved to attempt in this branch also the system of division of labour, which in the others had proved so advantageous. For this purpose, a few sappers of superior intelligence were selected, and trained each to one part of the operation. Its great divisions were, 1st, inking the plate and cleaning off the ink; 2nd, damping the paper; and 3rd, passing it through the press; but each of these had to be studied in its details. In the first, the best ink being required, the charcoal of vine stalks was obtained from Frankfort; the oil was burnt in a peculiar way to drive off the superfluous watery portion; and a careful manipulation adopted for charging the delicate parts of the engraving. To this one set of men were devoted; another set were instructed in the delicate handling of the plate in cleaning, which, instead of the system, usual at

that time of rubbing the plate with whiting by the bare hand, the tendency of which was rapidly to wear out the plate itself, was performed thenceforth by a process practised in Paris, and described in the Memorial Topographique, merely by fine muslin and alkaline solution. This saved nearly all the friction and wear, and was most successful; to this indeed, and to the care of these men, is to be attributed the very small injury which the plates sustained from the unparalleled number of impressions which were taken from them. It combined, in fact, the durability of steel plates, with the facility of correction, which is the chief recommendation of copper. The damping of the paper and passing it through the press was the final operation, which required care in the one process, with force and strength in the other. After this, the sheets were placed in milled glazed boards, under great pressure, to smooth and dry. These operations were all in progress together, the numbers employed in each being such that there should be no waiting in either, and the ultimate result was, that instead of twenty or thirty impressions in a day, the numbers taken frequently amounted to many hundreds, while the price was reduced from ninepence to one penny each, exclusive of material, which was, of course, the same in both cases."

"Perhaps it may not be out of place here to advert to a class of work, which subsequently became of importance, and the full results of which are yet to be seen. This arose, in the first instance, merely from the desire to ascertain a correct orthography

for the numerous names of places, more especially parishes and townlands, which alone amount to nearly 70,000, to be engraved on the face of the maps. These names were commonly of Irish origin, and frequently of great antiquity. Lieut. Larcom first began himself to study the Irish language, and investigate the names as they arose, but this was obviously insufficient, except to give him the means of devising a general system of research and controlling those who were to work upon it. This was ultimately accomplished by a party of persons employed for the purpose, and the operation consisted simply in reading all the sources of information, and extracting everything which bore on the names of the several localities. Many of these were in Latin, many in Irish, contained frequently in MS. charters and grants. When all had been collected that libraries and records could furnish, an investigation by a qualified Irish scholar was made on the ground, where by additional inquiries, conversation with the old inhabitants, an examination of the locality, little difficulty was experienced in discovering the meaning of the name, and its correct orthography. But it was not deemed proper, in all cases, to revert to the ancient spelling, now frequently obsolete: the practice, when this information had been obtained, was to adopt that one among the modern modes of spelling, which was most consistent with the ancient orthography. The documents thus collected form in themselves a most valuable topographic library, such perhaps as no country in Europe possesses in the

ndensed form. It subsequently became the
the historical branch of a Memoir, which it
posed should accompany the maps, as it must
ous that to trace all the changes which the
f a place has gone through, by studying all
ks in which mention of it occurs, is, in fact,
in review the whole history of the place."
late also, it has attracted the attention of
ien, in connection with the recent acts for
ation of Deeds, as preserving the *alias* names
various places, which in conveyances of pro-
r investigation of titles is usually a fertile
of confusion and delay. For this purpose,
ocuments may yet be found to possess a high
value, more especially when the Ordnance
hall be used for the registry of real property,
ie recent Act has been enjoined."
addition to the special charge of the depart-
r engraving and publishing the maps, Capt.
performed also the duties of adjutant or
-major, being the sole officer permanently at-
to Colonel Colby, at head-quarters. The
nployed on the survey of Ireland was on an
about 20 officers, 200 sappers, and 2,000
s, from 1828 to 1846, when the last county
npleted, and the greater part of the force re-
to England. The whole correspondence of
vey, both civil and military, within itself, and
e various authorities of the Ordnance and the
ment, as well as the accounts of an expendi-
nounting to £720,000, passed through the
iring the whole time."

To many the above extract may appear to relate rather to Lieut.-Col. Larcom than to General Colby, but such is not the case. General Colby did indeed avail himself of the services of one so able; but he was, at the same time, always present to aid him by his advice and judgment: and though, as a man of enlightened and liberal mind, he willingly listened to the suggestions or examined the projects of those serving under him, he was equally able and ready to point out their fallacy, or to explain their inapplicability; so that, in this, as in every other branch of the work, he is entitled not only to claim respect for the judgment he exhibited in the selection of his officers, and for the extreme liberality with which, forgetful of self, he allowed every one to work out an honourable name for himself; but also to have awarded to him the high honour of having planned such a work as the survey of Ireland, watched over the arrangements required in its progress, and secured its success by controlling the development of its organization in all its parts, and directing, either in person or by letter, all its operations; for when we look with admiration at this, or any other work, seen as a completed whole, and give praise to those portions of it which appear so excellent, we ought
to forget how much, which would have been
r relatively or absolutely bad, had been re-
and thrown aside, through the instrumentality
at superior mind and powerful will, which pre-
over and controlled the whole work.

PART III.

To close the Memoir of this distinguished member of our profession, it is now only necessary to consider him as a man of science, in reference to those operations of the survey which, like the observations of the practical astronomer, are classed together as scientific labours; and in this respect also it will be found that General Colby was not wanting in his efforts to maintain the high character of the British Survey, not only as a work eminently faithful in all its details, but also as having been marked by originality and boldness in its mode of execution. The origin and history of the British Survey have been already fully described in the first part of the Memoir; but for the present purpose it is necessary to take a wider range, and with the aid of the excellent article on the Figure of the Earth, by the Astronomer Royal, in the Encyclopædia Metropolitana, to sketch briefly the general history of those scientific operations which, undertaken for the objects of the philosopher, have everywhere terminated in practical works of the highest importance; namely in topographical surveys of the ground which either have already, or will hereafter, become

powerful instruments of national improvement. Familiar as almost every civilized inhabitant of the earth now is with its general form, as a nearly spherical planetary body, it may be fairly said that the first man, who not merely recognized its rotundity, (as several phenomena celestial and terrestrial may have led to at least a suspicion of that fact,) but who, occupying only a speck on the earth's surface, formed the bold design of attempting to measure it, must have been under the impulsive influence of a species of inspiration. The principle of determining the dimensions of the earth by measuring an arc of the meridian, or, in other words, of measuring spaces on various portions of a meridian corresponding to observed differences of altitude of the celestial pole, or of some heavenly body such as the sun or a star, and hence deducing the space in each portion corresponding to one degree of difference of altitude, or determining, as it is called, the length of a degree on the earth's surface, was that adopted by the Alexandrian astronomers, and has continued to be employed ever since.

Eratosthenes, about 230 B.C., observed that the sun was exactly vertical at Syene, in Upper Egypt, at noon on the day of the summer solstice, as the edges of a deep well threw no shadow on the bottom; and that at Alexandria the sun's zenith distance at the same season was 7° 12′, as measured by a vertical style fixed in a hemispherical bowl. He supposed the two places to be in the same meridian, and reckoning the distance at 5,000 stadia, estimated the

earth's circumference to be 250,000 stadia; but, as the length of the stadium used is unknown, this curious though imperfect operation serves only as a record of the lofty conception of its author.

Posidonius, contemporary with Pompey the Great, (about B.C. 50) made a rough guess, much inferior in accuracy to the operation of Eratosthenes. He observed that the star Canopus just touched the horizon at Rhodes, when at Alexandria he estimated its altitude to be $7\frac{1}{2}°$. The distance between these places he supposed to be 5,000 stadia, and hence estimated the earth's circumference at 240,000 stadia; but as refraction was then unknown, and therefore not allowed for, and no accurate estimation of the distance between the two places separated by the Mediterranean could be formed, the measurement can be only considered a very rude operation.

Ptolemy, A.D. 137, makes no remarks on the dimensions of the earth, but he cites the fact that eclipses of the moon are seen at different times as regards the noon of the places of observations at different points on the earth's surface, these places lying east or west of each other, as a proof that the earth is spherical; and as he states that the differences on the earth's surface are proportional to the differences of apparent time, he may be considered as the first who suggested the principle of determining terrestrial longitude by lunar eclipses. Ptolemy also remarked, as a proof of the earth's sphericity, that on going northward the number of visible circumpolar stars is increased, which could not be the

case, had the earth's surface been either cylindrical or a plane. He adopted 500 stadia as the measure of one degree, an estimate supposed to have been made by Marinus, the Tyrian, from observations of distant latitudes, compared with the rough measures of distance made by sailors.

A long interval now succeeded without any renewed attempt to measure the earth, when at length the Caliph, Abdalla Almamoran, who began his reign at Bagdad, A.D. 814, selected a spot on the plains of Mesopotamia, and directed one company of astronomers to proceed northward from that point, and another southward, until each should find a difference in the latitude, or altitude of the pole, of one degree, the distance being measured by rods. One party found the distance, or length of a degree, 56 miles of 4,000 cubits, and the other $56\frac{2}{3}$; but as the true length of the cubit is not known, this measurement must also be considered only a scientific curiosity. Another period of 700 years had elapsed, when Fernel, a Parisian, published, in 1528, the account of a measure made in the neighbourhood of Paris. On August 25, he observed the sun's meridian altitude at Paris, and going northward one degree, as nearly as he could judge, he again, on August 29, observed the sun's meridian altitude. His angles were measured with a triangle, not a quadrant, one side of which, 8 feet long, was kept vertical, whilst another ovided with sights was moveable round the point connection with the first, and the third side being ected with, but moveable on the other sides, and

graduated as a line of chords to every minute of the quadrant, served to measure the angles. The distance was calculated from the number of turns made by the wheels of Fernel's carriage, and the length of the arc he deduced was 56,746 toises, a remarkable approximation to the results of modern observations, which is about 57,060 toises.

Snell published at Leyden, in 1617, the result of a measure remarkable as being the first in which the distances were determined by trigonometrical operations instead of by direct measurements with rods or perambulators. He measured a base of 326·4 Rhinland perches, and two bases of verification of 348·1 and 166 perches, the perch being 12 feet, and measured his angles with quadrants and semi-circles. From the distance between Alcmaer and Bergen-op-Zoom, as thus determined, he deduced the length of a degree = 28,473 perches, and from the distance between Alcmaer and Leyden = 28,510, and he finally adopted 28,500 perches as the length of a degree.

As Snell had carefully compared his standard with those of other nations, his measure was easily reduced to French toises, when it gave 1° = 55,100, and after the re-observation and re-calculation of the latitudes by Muschenbrock, in 1729, 1 = 57,033 toises: a proof that this early operation was conducted with great ability and care.

In 1637, Richard Norwood published the account of his measurement, being the first by an Englishman, with the exception of Wright's inference of the

semi-diameter of the earth from an observation of the dip of the horizon at Mount Edgecombe. By means of a sextant of more than 5 feet radius, he determined the difference of latitude between London and York to be 2° 28′, and the distance between the two places he determined, partly by measuring along the road with a chain of 99 feet, taking the bearing of each line with a circumferentor and reducing these lines by a table, and partly by pacing. From these data he found 1° = 61,199 fathoms.

Riccioli's trigonometrical measurement in Italy was effected about this time, but his measure was very erroneous. His method of determining the arcal distance between two stations, was by observing the depression of each from the other.

In 1669 Picard commenced his trigonometrical measurement, which notwithstanding an error of six toises in his base and some other defects, may be considered superior to any which preceded it, and is especially remarkable, as having been the measure used by Newton in his Principia, published in 1687. The extremities of Picard's arc were Sourdon, near Amiens, and Malvorsine, near Paris. His base was 5643 toises, and his base of verification 3902. The difference of latitude between Malvorsine and Sourdon was found to be 1° 11′ 54″, and between Malvorsine and Amiens, to which the arc was extended, 1° 22′ 55″, the corresponding arcs being 68,439, and '8,850 toises, the first of which gave 1° = 57,064 ses, and the second 1° = 57,057, or a mean value 1° = 57,060 toises = 60,812 fathoms. Mauper-

tuis, Clairaut, and others, having repeated the astronomical observations in 1739, the value of 1° was found to be 57,183 toises.

As already observed, Picard's measure was used by Newton, and confirmed the theory of universal gravitation, by reconciling it to the lunar motions, the consideration of which Newton had been obliged to lay by for a time from the want of such a measure, as he was not aware of the measures of Snell and Norwood, and assumed a degree to be 60 miles, as it was then commonly reputed to be. It is impossible not to feel additional admiration at the intellectual pre-eminence of Newton, when it is remembered that he was thus obliged to look to Flamstead for the celestial observations, and to take from Picard the terrestrial data, necessary to enable him to demonstrate that the grand conception of universal gravitation is a mathematical truth. In 1673 the doctrine of centrifugal force was first satisfactorily explained by Huygens, and combining this theory with the properties of fluids, Newton showed that the earth is not a sphere but a spheroid; that its equatorial diameter is longer than its axis of rotation; and that, supposing the earth to have been in the state of a homogeneous fluid, the proportion of the diameters may be taken as 229 : 230. Well might the work "The Principia," published in 1687, which contained such daring enquiries and such noble results as these, be looked upon as something more than human. In 1690, Huygens published his Treatise "De Causa Gravitatis," and assuming the

attraction upon every particle to be directed towards the centre, and to be always the same at equal distances from the centre, a supposition opposed to Newton's principle that every particle attracts every other particle, he found the ratio of the axes to be 578 : 579.

It is rather curious that Svanberg, (1805,) by confounding together the two works of Huygen's, makes these latter deductions precede those of Newton. His words are, "The first results of the theorem (the dynamical theorem respecting centrifugal force), announced by Huygens, were the inequality of the force of gravity under different heights of the pole, from which, in consequence of its diurnal motion, it was necessary that the earth should have a protuberance towards the equator and flattened at the poles. These discoveries were precursors of the hypothesis of universal gravitation, or attraction, afterwards proposed by Newton : a hypothesis which has entirely changed the aspect of Astronomical science, and from which must be dated the ever memorable epoch of the birth of 'Physico-Mathematical Science.'" Newton however had conceived the sublime idea of universal gravitation, probably as early as 1666, and was only obliged to defer its elucidation and promulgation, until he had obtained a tolerably correct measure of a degree (that by Picard), on which to verify his calculations of the lunar motions.

At such a period in the advancement of human knowledge, some more powerful means of calcula-

tion became necessary towards the full development of the great physical theories, which from time to time began to present themselves to the human mind, it seems as if an inspiration, similar in character to that which first suggested to Newton his noble conception of the great laws which bind the planetary bodies together and regulate their motions, must have also suggested to him a calculus suited to their mathematical representation, as it was at that time that he invented the Fluxional Calculus. This is not the place to enter into the controversy with Liebnitz on this subject, but though the differential calculus has now succeeded the fluxional, and been universally adopted by mathematicians as the most powerful instrument of the two, the fluxional bears upon it the stamp of originality, and could have sprung from no mind less imbued with the highest geometry than the mind of Newton was. Svanberg, after describing Newton's theory that the earth is an ellipsoid of revolution, such as it would have become if supposed to have rotated in space when in a fluid state, observes, "The truth of the hypothesis of Newton was demonstrated for the first time by Maclaurin (1740) with that rigour which characterized his works, and which, so long as the taste for the exact sciences shall not be extinct in our enervated race, will secure for his 'Treatise of Fluxions' the glory of being one of the most sublime productions evolved from the constructive spirit of the ancient geometers."

It was only natural that such results, not merely

expressing the magnitude but the actual form of the earth, should command the attention of philosophers; but they were soon doomed to be called in question. In 1684, J. D. Cassini had commenced a trigonometrical measurement of an arc of meridian in France, having taken Picard's base as a foundation for his work, and proceeding thence southward. This arc was intended to form the basis for a general map of France, and the subsequent more accurate measurement of it was actually so applied; affording therefore an exemplification of the ultimate practical value of such operations, however purely scientific and philosophical may have been their primary object. This arcal measurement was completed in 1701, and a northern portion, extending to Dunkirk, in 1718. A base of 7,246 toises was measured near Perpignan, and one of 5,464 toises at Dunkirk. By the southern section of the arc was deduced $1° = 57{,}097$; by the northern $1° = 56{,}960$; a result tending to show that the degrees became shortened in going from the south to the north, or that the earth was a prolate spheroid, the ratio of its axes being nearly 95 : 96. A deduction so entirely opposed to the theory and determination of Newton, roused the attention of Mathematicians, and as the Cassinis maintained the accuracy of the measurement and of the form of the earth deduced from it, the French Academicians proposed, and the French government supported, the design of measuring an arc near the equator, for comparison with that measured in France; and almost simultaneously it was

resolved to measure another as far north as possible; one of the most noble scientific schemes which had ever been projected being thus undertaken as one great whole. In May, 1735, Bouguer, Godin, and Laeondamine, sailed for America, and having crossed the Isthmus of Darien, proceeded to Peru, where, aided by some Spanish officers, they effected the measurement of an arc of 3° in the great valley between the two principal chains of the Andes. The northern limit of the arc was 2½° north of the equator, and the southern 3°, 4½° south of it. The base of 6,272 toises was measured near Quito, near the southern extremity of the arc, and a base of verification of 5,259 toises, near the northern extremity, the lowest portion of this remarkable arc being 1½ miles above the level of the sea, and some of the adjacent trigonometrical points differing from each other in altitude more than a mile. The physical difficulties of this measure, and the dangers from the ill-will of the natives, were very great, but the ingenuity and perseverance of the observers triumphed over them all. The difference of latitude was 3° 7′ 1″, and the arcal distance measured 176,645 toises, whence 1° = 56,767 toises, or, reduced to the level of the sea, 56,748. The northern arc was measured by Maupertuis, Clairaut, Camus, Lemonnier, and Outhier, who arrived in the Gulph of Bothnia in July, 1736; they selected the valley of the river Tornea as the site of their arc, using the hills on each side for their stations, and after suffering much from cold, fogs, and other inconveniences, arri-

after sixty-three days of fatigue at Kittis, a mountain selected as the northern extremity of the arc. On returning to Tornea, finding the river frozen, they measured their single base about the middle of the arc, when, not being quite satisfied with some of their results, they re-observed the latitudes and completed the observations of the three angles of some of the triangles, deducing as their final conclusion a difference of latitude $= 0° 57' 27{\cdot}6''$, an arcal distance of 55,023 toises, and hence $1° = 57{,}422$. The latitudes were observed with a sector made by Graham; and in addition to the observations connected with the measurement, others were made, as in Peru, to ascertain the length of a pendulum vibrating seconds, all agreeing in showing that gravity increases in going from the equator to the pole, thus confirming the evidence of the arcal measurements. Whilst these works were in progress, J. Cassini, Cassini de Thury his son, and Lacaille had re-measured the French meridianal arc, and by the aid of new bases and new observations had discovered the cause of the former difficulties, partly due to an error in Picard's base equal to $\frac{1}{1000}$ part of the whole, and which affected only one part of the arc, and partly to some inaccuracies in Cassini's work. From this new measurement it was found, that between Perpignan and Rodez $1° = 57{,}048\frac{1}{2}$ toises; between Rodez and Bourges $1° = 57{,}040$; between Bourges and Paris $1° = 57{,}071$, and between Paris and Dunkirk $1° = 57{,}084$. An arc of parallel was also measured across the mouth of the Rhone, the dif-

ferences of apparent times, and hence of longitude, being determined by observing, from the two extremities of the arc, the explosion of gunpowder, as a signal, fired from the top of a church intermediate between them, and the degree of this arc of parallel in latitude 43° 32′ was found to be 41,617·6 toises, whence comparing it with the arc of meridian between Perpignan and Rhodez, an ellipticity of $\frac{1}{168}$ was deduced. A comparison of the new arc of meridian, in France, taken as a whole, with the Bothnian or Lapland arc on the north, and the Peruvian arc on the south, showed that the degrees increased towards the pole, and therefore confirmed the Newtonian theory; but whilst a comparison of the French arc with the Peruvian gave an ellipticity of nearly $\frac{1}{3^{1}_{4}}$, a similar comparison between the Peruvian and Swedish gave $\frac{1}{213}$, showing, provided all the measurements were quite correct, an irregularity in the figure of the earth which has since so much exercised the ingenuity of Geodesists, and led to the re-measurement of more than one arc. The Lapland arc was re-measured by Ofverbom, Svanberg, Holmquist, and Palander, in 1801, 1802, and 1803. In the Preface to the description of this work by Svanberg, M. Melanderhjelm, to whose exertions and influence with the King of Sweden must be ascribed the liberal manner in which it was carried out by the Swedish government, states "that it would be hard to give credence to the hypothesis of an irregular form of the earth; and as it must be admitted, if the former measurement should be proved to be

correct, it appears only reasonable to endeavour, by renewed measures, either to establish the accuracy of the former results, or to correct them." In 1799, therefore, he requested Svanberg, Director of the Observatory of the Royal Academy of Sciences, who was about to visit his native country, in the vicinity of Tornea, to look after traces of the old arc, and to examine the mountains especially, in order to judge whether their attraction could have affected in any marked manner the sectorial observations. Svanberg considered, after a careful examination of the mountains, that no appreciable effect on the results could be ascribed to that cause, nor did he discover any other cause sufficient to account for the anomaly which the comparison of the previously measured arcs had brought to light. This report of Svanberg convinced Melanderhjelm of the necessity of new measurements, and backed by the representations of the Royal Academy of Sciences, he laid the case before the King, who at once in the most liberal manner sanctioned the project. Ofverbom, who was associated with Svanberg, was Chief Topographical Engineer in the Land Office. The Academy of Sciences took care, on Melanderhjelm's representation, to supply their delegates with the very best instruments they could procure; a repeating circle having been ordered for them from Lenoir of Paris, and made under the immediate inspection of Delambre. The French Institute also presented to the Swedish Academy a carefully prepared copy of both the metre and the toise, to be used as standards in

the comparison of the measuring rods. The actual measuring instruments were iron rods, 6 metres long, to which further reference will be hereafter made. The summer of 1801 the astronomers devoted to exploration, and in January, 1802, provided with their instruments, departed for Lapland, from which country they returned in the month of March, 1803. The length of the arc measured was 1° 37′ 19·57″, between Mallorn and Pahtavara, and at the latitude 66° 20′ 10·05″ 1° = 57, 196·16 toises; or supposing that the French double metre had not been regulated for zero, but for a temperature of 61¼ of Fahrenheit, 1° = 57,185·52. Again, using the refractions of Prony, instead of those of Bradley, in calculating his latitudes, Svanberg made the first of these results 57,188·43 toises, and the second 57,177·80; whilst it should be remembered that Maupertuis deduced from his measurement 1° = 57,422 toises, being more than 200 toises in excess of the more modern measurement. In respect however to this measure, satisfactory as it appears in removing the difficulty which had before embarrassed the subject, Airey rightly remarks that it does not account for the difference between it and the old measure, as the geodetic measures of the two operations agreed very well, and the latitude of Tornea, determined by Maupertuis, agrees perfectly well with Svanberg's observations, whilst unfortunately the Swedish astronomer did not repeat the observations at Kittis, the only place where an important error could be expected to be found. Prior to Svanberg's measurement, the

great geodetical operation of measuring the length of a quadrant of the meridian, passing through the Observatory at Paris, in order to determine the new standard of measure, which was to be the $\frac{1}{10,000,000}$ part of that quadrant, and to be called a metre, had been undertaken by the National Convention of Paris, and carried through by Delambre and Mechain, with instruments which will require a further notice hereafter. This great arc was measured amidst all the ferment of the revolution, and was therefore a work of no ordinary personal danger: it extended from Dunkirk to Barcelona, following, in fact, the course of the former arc, and was subsequently extended by Biot and Arago to the Island of Formentara, near Minorca, and dividing the whole into five parts, of which this extension is the 5th, the values were, proceeding from the north to the south, $1° = 57,082·7$, $1° = 57,068·8$, $1° = 56,977·8$, $1° = 56,946·6$, $1° = 56,956·4$, and, further, the mean latitude of the whole arc, from Dunkirk to Formentara, is 44° 51′, and the mean length of a degree, 57,006·6. Now Svanberg, comparing his degree with the value of the Peruvian degree, deduced a flattening of $\frac{1}{331·45}$, and with the French degree, as determined by Delambre and Mechain, a flattening of $\frac{1}{326·89}$; and making the comparison with the Peruvian, French, and East Indian degrees, a flattening of $\frac{1}{322·06}$, the old anomaly disappearing.

For the present purpose it is not necessary to dwell on other arcs, such as that measured by Lacaille, in 1752, at the Cape of Good Hope, and

subsequently re-measured by Maclear; the remarkable arc extending over about 100 miles, measured in 1764, by Mason and Dixon, in the present United States, with rods, without the aid of a triangulation; the very extended arcs measured in the East Indies, and alluded to in the earlier pages of this Memoir; and the minor arcs measured in Italy and other countries, as the object of this brief summary is not so much to give a general history of such operations, as to enable the reader to judge of the position maintained by British geodesists, in respect to their own arcal measurements and surveys.

Although great triangulations have since been adopted as preliminary operations in all national surveys, and the philosophical element, or that connected with the measurement of degrees, became secondary, or incidental, as it were, to the more practical one, such was not always the case; and, as before stated, the British, as well as the French survey, derived their origin from the philosophical operations directed to the determination of the figure of the earth. The origin of the British survey has been already thus explained, and it remains only to state, in respect to it, that as a work it was commenced with all the characters of originality, the genius of Ramsden supplying for its use a noble 3 feet theodolite, with which its terrestrial angles were to be taken, a still more splendid 9 feet sector for the astronomical observations, and the beautiful chain which replaced the rods, whether deal or metallic, with which other bases had been measured.

or the deal and glass rods which were first and successively used on the British survey itself. Justly then it may be claimed for General Roy, the first conductor of this work, that he attempted to remove every chance of error, and to introduce an amount of precision scarcely then to be thought of; or in Airey's words, "we believe it may fairly be said that in this, as in other grand experiments, though we began later than our continental neighbours, we conducted our operations with a degree of accuracy of which, till that time, no one had dared to form an idea." At the time the British survey commenced, base lines had been always measured with some description of rods, and they were in consequence tried by our geodesists, but quickly abandoned for the chain, which may be called an English instrument, and for the number of years which elapsed from the commencement of General Roy's measurement to the preparations for the survey in Ireland, Ramsden's chains had been used in measuring bases wherever required on the British survey; but, in the interval, a new principle had been adopted by Delambre and Mechain in the construction of the rods used by them in the measurements required for proving the length of the metre; and this improvement ultimately led to the abandonment of the chain in the British survey.

In all simple rods or chains it was necessary to determine their length at some definite temperature, and to reduce the measure made at any other temperature to its equivalent at the standard one; hence,

of course, careful observations were required, and records of the temperature, as shown by thermometers in contact with various parts of the chain, the reduction then being made consistently with the known experimental law of dilatibility of the substance of which the rod had been made. Without doubt very great accuracy was attained in this way, and as Svanberg even adhered to the system of simple metallic rods in his Lapland measurement, it may be well to describe and figure his apparatus as a late exemplification of this simple mode of measuring. The bars (Fig. 1) were strongly made of iron, 6 metres (19¾ feet nearly) long, 1 inch wide, and 1¼ thick, the ends A B C D, E F G H, being coated with silver, having a transverse line on each end, marking off the exact termination of the 6 metres; and calling these lines *a* and *e*, the line *a* of the second was made in laying the bars to coincide with the line *e* of the first, and so on successively. In using these bars it was necessary to guard against any alteration, except that due to change of temperature, such as alterations which might have been the result of their bending when moved along, and for this purpose a trussed plank, Fig. 2, was contrived for the purpose, the screw G K passing through it admitting of the most minute adjustment. On the plank were fixed perpendicularly three brass plates, C, D, E, which supported the rollers on which the measuring rods were intended to rest. Through the plates were drilled small holes, *c*, *d*, *e*; a silk thread passing through them was stretched from

to *e*, and if found quite free in hole *d* proved that the three holes were in a vertical plane, and as the silk line must necessarily assume the form of a catenary, any variation in the positions of the holes by an alteration in the primitive flexure of the board would be at once detected, by the movement of the silk cord, upwards or downwards, in hole *d*. Svanberg enters into a detailed calculation of the probable amount of variation in the silk catenary, consequent on a varying flexure in the plank, and the effect of such variation and flexure on the length of the measuring rod, and ultimately on the length of the base, and states that after frequent comparisons during the measurement of the base, the versed sine of the catenary never varied more than $\frac{1}{8}$ of an inch, and that the whole correction on the base required by that flexure would not amount to that quantity, $\frac{1}{8}$ of an inch. The plate D was provided with a lateral micrometrical movement to adjust the line laterally. During the measurement the bars were compared with the standard double metre, Fig. 3, No. 1; and to facilitate the comparison Svanberg adopted the following ingenious arrangement: two metal cubes, No. 2 and 3, were made and most accurately planed and polished, so that being brought in contact with the ends of the standard and firmly pressed by screws against them, they formed with the standard, as it were, one bar, Fig. 4, the line of junction exhibiting finer mark, or line, than could have been formed by cutting such a line on the surface of a bar. With 1 compasses the length of the standard was then

set off upon one of the measuring rods, and this was compared with the other rods by means of a curiously shaped compass, Fig. 5. The other details of this operation may be studied in Svanberg's account of it 1805; but it seemed desirable to give the preceding extracts, as being interesting illustrations of the contrivances adopted to ensure the utmost precision in the mode of measuring by simple rods or bars, which, after all, will be the method most generally adopted as being the most readily applicable to ordinary circumstances.

In the rods hitherto mentioned, the corrections for temperature required to be made from the observation of thermometers attached to, or in contact with them, the rate of dilatibility of the substance being known; but it is now necessary to consider rods which either measure their own change from temperature, or correct that change by their own movements; and for this purpose it is desirable to take a brief review of the history of pendulums, which, indeed, merit attention as being instruments which in one of their forms, have co-operated with arcal measurements in the determination of the figure of the earth. The discovery by Galileo of the isochronal property of the pendulum's vibration led to its application to clock work, and the priority of its use in this way has been disputed by Vincentio Galileo, son of the great Galileo, and by Huygens, the latter claiming to have made a really scientific pendulum clock before 1658, though Galileo may have made some rough experiments on the subject so early as 1649. The pendulum, thus applied, how-

ever ingenious, was still subject to the variations consequent on changes of temperature, as the isochronism only holds good in circular arcs of the same degree of vibration; and the cycloid is the only curve in which the vibrations, whether short or long, are performed exactly in the same time. Huygens invented also an ingenious mode of making the pendulum vibrate in the cycloidal arc, but it has not been found practically useful.

The error in time, consequent on the changes in the length of the vibrating arcs, is due to the variations in the maintaining power consequent on alterations in the amount of friction; but there is another cause of error in time, due to variations in the length of the pendulum itself, consequent on changes of temperature. M. Lalande found that the length of a rod or bar of iron, forming a second's pendulum, was altered 0·178 of an inch by a change of temperature = 67½° Fahrenheit, so that, being regulated in summer, it would gain 20 seconds per diem in winter; and it became necessary therefore, for all purposes in which precision was essential, to devise some mode of correcting or neutralizing the expansion and contraction; or, in other words, to contrive a compensation pendulum. Graham invented for his purpose the mercurial pendulum, which consisted of a steel rod 44 inches long, the lower end of which carried a large glass jar containing mercury, the diameter of the jar being about 2 inches, the height of the column of mercury 7½ inches, and its weight from 10 to 12 pounds. In this manner,

from the much greater rate of expansion of the mercury, the expansion of this small column counteracted the expansion of the rod and kept the centre of oscillation at the same distance from the centre of suspension. This form of pendulum was much improved by Mr. Frodsham, of the well known firm of chronometer makers, Parkison and Frodsham, who made such a clock for the College of Virginia in America, in conformity with the wishes of the late President Jefferson, the clock having been ordered by Mr. Peter Barlow, so well known to many of us, as one of our former most respected mathematical masters. The gridiron pendulum invented by Harrison, has, however, more connection with the present subject, and has, of all pendulums, been most generally adopted. It consists of nine round rods, five of steel and four of brass, arranged in one plane side by side, and made respectively of such lengths, that owing to the excess of expansion of one metal over the other, the centre of gravity should be moved upwards, notwithstanding the general elongation. The two outer bars are of steel, and being joined together by cross-pieces at top and bottom, form an exterior frame; to the lower cross-piece are fixed two brass rods, within and parallel to the two iron rods, one on each side, their tops being connected by another cross-piece, made free to move within the outer frame of steel rods; to this cross-piece is now attached a pair of steel bars within the brass rods, and both are joined together at their lower ends by a fourth cross-p-

which supports, as in the case of the first, another pair of brass rods, which are in like manner joined together at their summits by another cross-piece, from which is suspended the fifth steel rod which carries the pendulum bob. Now, in this case, it is manifest that as the whole pendulum is suspended by the frame formed by the outer steel rods and their cross-pieces, the expansion begins from the top and extends downwards, the steel rods carrying down with them the lower ends of the brass rods, the expansion of which may therefore be considered as commencing from below and extending upwards, so that the length of the rods being made inversely as their powers of expansion, the distance of the centre of oscillation from the point of suspension may, as in the mercurial pendulum, be kept invariable. In this case all the steel rods may be considered as expanding downwards, and all the brass rods as expanding upwards, and as these are arranged in pairs, with the exception of the centre steel rod, it may be said that three steel rods expand downwards and two brass upwards, the proportion therefore being as 2 : 3; but though five rods would thus be theoretically sufficient, nine are used in order to support equally the centre rod on both sides, so as to avoid twist and shock.

The several modifications of the gridiron form of ndulum are fully described in the article on manu- es and machinery, by Mr. Peter Barlow, in the cyclopædia Metropolitana, to which reference may de. The principle itself may be considered that

of the measuring rods adopted by the French though the object of their rods in here was not to compensate for the variation of length due to change of temperature, but to measure its amount. The mode in which this was attained will be understood by reference to Fig. 6, which however is simply an illustration of the principle, and not of the details of construction. Let *s* then be a flat bar of zinc, resting on and in contact with *b*, a similar flat bar of platinum, *a* being bevelled off at one end, and at the other connected with *b* by a screw. Now the expansion of platinum is only $\frac{1}{m}$ part for 180° Fahrenheit, whilst zinc expands $\frac{1}{n}$ part for 180°, so that, between the freezing and boiling points of water, a platinum rod 20 feet long would expand 1·11 tenths of an inch, and a zinc rod of the same length 7·06 tenths, and in 90° the platinum rod 0·55 tenth of an inch, and the zinc 3·53 tenths; or generally, if *n* be called the expansion of the platinum bar, between the freezing and boiling point of water, n + a may be called that of the zinc or other metal associated with the platinum, and the expansion in $\frac{1}{10}$ or any other proportion of the 180° $\frac{1}{10}n$, or $\frac{1}{m}n$, in the platinum bar, and $\frac{1}{10}n + \frac{1}{10}a$ or $\frac{1}{m}n + \frac{1}{m}a$ in the zinc. If then a scale be formed on the platinum bar 5·95, or 6 tenths of an inch nearly, in length, and divided into eight parts, each of these parts will represent the difference of expansion of the two metals in 10°. Now this scale commencing at the line formed at the end of the zinc bar the

two rods being then at the temperature of 32° as zero, and continued backwards also for about 10° of temperature, when the two bars begin to expand together, *a*, the zinc bar, will pass over one space for every 10° of change, so that, reading this change by a microscope, provided with a micrometer for subdividing the divisions of the scale into tenths and hundredths, the change due to one degree, or to $\frac{1}{10}$ of a degree, would be detected. The variations in the lengths of the platinum bar, corresponding to any changes of temperature, or in other words, to the difference of expansion or contraction, as shown by the scale, namely, the $\frac{1}{m}$, corresponding to the $\frac{1}{m}$a, being tabulated, the necessary reduction would be known at once by inspection. On this principle the French measuring rods were constructed, but it will at once be perceived that the friction of the two bars, necessarily in close contact with each other, and their different times of heating and cooling may have occasionally had considerable influence on the results; still, however, the contrivance was very ingenious, and the arcal measurements of Delambre and Mechain, in which these bars and the repeating circle were the distinguishing instruments, must be looked upon as one of the most able works of the kind ever executed.

When the Irish survey therefore had been determined upon, it became necessary for its appointed chief, Major Colby, to consider whether he would continue to use the chain of Ramsden for measuring

the new base lines, required as a foundation for that survey, or whether he should adopt either the French bars or some modification of them. This enquiry might not indeed have originated in another man, but Major Colby lived, as it were, in an atmosphere of science, belonging as he did to almost every scientific institution of the metropolis, and as, independently of the public meetings of such learned bodies, he dined three or four days a week, during the season, at their clubs, he was constantly engaged in hearing of and discussing the merits of the inventions of foreign countries. His active mind therefore became imbued, not only with a knowledge of what had been done, but with an earnest desire to advance still further the progress of geodetical science; and this ardent zeal, and craving for improvement spread quickly amongst the young officers serving under him, and setting them also thinking and working, rendered the winter of 1824, 25, memorable in the annals of the survey, for the activity of mind and energy of purpose, which were so strikingly exhibited by the survey officers then in London, the head quarters of the survey being the Map Office in the Tower. The officers who took a part, either by head or hand, in these proceedings, were Captain Mudge, Captain Robe, Lieutenant Drummond, and Lieutenant Murphy, all of whom have since died, the two first having attained the rank of lieutenant-colonel, and Lieutenant (nov Lieut.-Colonel) Dawson, Lieutenant (now Lieut.-Colonel) Larcom, and the writer of this Memoir

The quarters, in Furnival's Inn, of Lieutenant Drummond became a laboratory and a workshop, and diligently did the highly gifted officer labour to produce a measuring apparatus which should be free from the alleged defects of those hitherto used. His last and favourite scheme was a riband, formed of slips of mica, and which it was supposed would be almost invariable in length, from its very low degree of dilatibility. As however this riband would have required to be supported, like the measuring rods of Svanberg, by a trussed plank, and to be kept straight by weights, it did not appear to ensure permanency of length, even had it been admitted as true that mica undergoes little perceptible extension by heat. During his trials Lieutenant Drummond suspended the riband of mica by iron wires, but this system would not have answered in practice, as the expansion of the wires by heat would have affected their rigidity, and rendered different weights necessary for retaining them in one constant state of curvature. Encouraging his officers, as Major Colby did, to pursue these enquiries, and taking the greatest interest in the results of their efforts, he did not himself remain idle; and though, from his apparently careless manner, they scarcely looked upon him as a rival, the Master soon proved that in the race of invention he was able to beat even the most ingenious of his "Boys," as he familiarly called his officers.

It is necessary that I should here speak in the first person, in order to convey graphically the first steps of Major Colby's invention. Every one who

knew him in those days must remember how rapidly he moved or ran through the streets, rarely relapsing into a simple walk; and it was thus that I met him rapidly descending Tower Hill, when he took my arm, and with the usual "Come my boy, I have something to talk to you about," carried me back with him to the Map Office in the Tower, which was not only the office for the business of the survey, including the engraving of the maps, but also contained the private apartments allotted to Major Colby, as director of the work. When once there I was detained for the evening, and after dinner Major Colby explained to me fully the idea he had formed of a compensation measuring rod. In the gridiron pendulum the motion of the centre of oscillation is the resultant of the motions of the two sets of metallic rods, the motion in one direction counteracting that in the other, and the resultant being therefore 0; in the mode proposed by Major Colby, two bars of different metals were to be fastened together in the centre (Figs. 7, 8), and as the expansion or contraction of these bars would necessarily be in the same direction, the compensation was to be effected by connecting with them a transverse tongue $a' b' n'$, Figs. 7, 8, 9, the bar $p a'$, Fig. 7, expanding beyond the bar $q b'$, and necessarily producing rotation on the pivots $a' b'$, Fig. 9, as the tongue advanced to the position $c' d' n'$, or when it receded to that of $e' f' n'$ in contraction. see Fig. 7: the point n' being so adjusted that it should be kept, by this compound motion, always

in the original line a' b' n', when the bars are of the same length, that line being determined at some definite temperature, namely 32° or 60°, or 50°, which in this particular case appears preferable, as being about a mean temperature between the probable extremes in this country; in warm countries the mean should be taken higher. This very beautiful principle is that of Ellicot's pendulum, though Major Colby was at the time quite unacquainted with this application of the principle. In Ellicot's pendulum the bars or rods of the two metals were kept in close contact by screws, fixed in the iron pendulum rod, which formed one of the bars, whilst the brass bar was permitted to move freely along the face of the iron bar, by slits wider than the body but narrower than the heads of the screws which played, as it were, in them. Immediately below the brass bar the iron bar was widened, and two steel levers, one on each side of the extremity of the brass bar, were pivoted into it, one end of the pivot turning in a socket formed in the iron bar, and the other end in a similar socket formed in an outer plate, screwed on to the iron bar. The pendulum ball was supported by screws, connected with the ends of the steel levers, and its weight depressing the long ends of the levers caused the short ends to press against the ends of the brass bar, so that when the two rods expanded together, the expansion of the brass exceeding that of the iron, the short ends of the levers were depressed and the long ends elevated, by which the pendulum ball was also elevated,

and the effect of expansion, in lowering the ball, counteracted. Two differences between the pendulum and the measuring rods will be readily appreciated by the description here given; the first, that Major Colby kept his rods apart from each other, and thus avoided the effects of friction; the second, that in the pendulum the levers were only connected with the iron rod, and not with both rods, as in the measuring apparatus. In the pendulum, the levers turned freely round one centre, and there was no twist or distortion, whereas in the measuring rods, as the levers turn on two centres, Fig. 9, it is evident that the ends of the bars, if tightly pivoted, will be pulled together whenever the line $a'\ b'\ n'$ ceases, from the expansion or contraction of the bars, to continue perpendicular to them.

Having listened attentively to Major Colby's explanation of the principle of his proposed compensation measuring rods, I felt satisfied that it would succeed in practice, but such was not the opinion of all the members of our little senate, as Lieutenant Drummond was, in the first instance, more disposed to pursue his own enquiries, and expected a better result from them than from the proposed bars of our chief. I accompanied however Major Colby to the house of Mr. Troughton, and when that first of British scientific mechanists had expressed his ready assent to the principle, and promptly offered to prepare a small model bar, there could be no longer a doubt of success, as every one who has had any occasion to consult Mr. Troughton well knows that he

was not more distinguished for his high talent than for the frank and honest expression of his opinion. Some, doubtless, have at first felt mortified when some darling project has been overthrown by his abrupt, "Well, what is there in that?—there are many better things of the kind already;" but if so, they have at other times accepted his approval as the most gratifying and certain proof of merit in their designs, as he never flattered—never deceived. The small 3 feet model bar was rapidly made, and from that moment Drummond became the most able and active assistant of Major Colby, in conducting all the preliminary experiments. From the model bar Troughton proceeded without delay to the construction of a complete set of measuring bars, a ready assent having at that time been given by the Government, and especially by the Duke of Wellington, then Master-General, and by Sir H. Hardinge (Viscount Hardinge), then Clerk of the Ordnance, to any proposition of Major Colby for giving perfection to the Irish survey in every branch of its operations. The metals adopted were iron and brass, and each bar was 10 feet 1½ inch long, ½ inch broad, and 1½ inch deep, being placed at 1·125 inch apart. Now let $a\,a'$, $b\,b'$, Fig. 7, represent these bars being united together at their centres by a steel bar $p\,q$, but allowed to expand freely towards the extremities, and let the brass bar, in expanding by a small increase of temperature, extend to $c\,c'$, and at the same time the iron bar to $d\,d'$, it is evident that the steel levers or tongues $a\,n$ and $a'\,n'$, at the ex-

bars, which move freely, but
on conical pivots, which allow the
(riate slightly from the perpendicular,
wing the bars together in the manner
l to, will at the same time pass from
positions *a b n*, and *a′ b′ n′* to the
d *c′ d′ n′*, and *n n′* will remain at the same
t when the points have been so arranged
b d :: *a n* : *b n*, or the expansion of the
expansion of the iron :: the distance
ompensated point *n* to the pivot of the
: the distance from the compensated point
ot of the iron bar. The two bars are placed
e g f h, Fig. 8, on the bottom of which are
at $\frac{1}{4}$ and $\frac{3}{4}$ of the length, to hold the rollers
ch are intended to support the bars, whilst
is a vertical brass stay which rises between
l cylinders *s s′*, by which the bars are tied
, and thus prevents any accidental move-
the bars in a longitudinal direction. The
are secured from injury by a species of
a ched to the box at *o o′*, having a small
opening provided with a lid, through which
pensated point may be seen; and at *i*, at-
to the brass bar only, is a long level which is
ed through a glass window forming part of
of the box; *m m′* are two pieces of metal
over the rollers which support the bars, and
to prevent them from being thrown by any
jar against the lid of the box; at each end
box on the outside, is screwed a thick meta

plate, for the purpose of firmly fixing a three-armed grooved stand, intended to support the tripod of the compensation microscope, by which the connection between successive rods is made, see Fig. 11; and for putting the bars approximately in line there is a vane sight at each end of the box, which is turned down, when not in use, on its hinges, into grooves.

The mode of placing the rods may be seen in Fig. 11; first there are the pickets P P, P′ P′ driven into the ground at proper distances, and in the proper line approximately; the pickets are placed three and three together, and their heads levelled so as to support triangular frames R R′; on the frames are placed the "trestles" T, and on them tripods L L′, which are adjusted into line by a directing telescope, and carefully levelled in respect to each other, and laterally also, so that when the bars are laid upon them they shall require as little adjustment as possible. On the tops of the tripods are rollers for supporting the bar box, and one is provided with adjusting screws for moving the box longitudinally, laterally, and vertically; the tripods are technically called camels. Six of these bars were used in the field, being designated A, B, C, D, E, G, and the weight of each bar with its brass ends is 136lbs. In ordinary rods, the usual mode of connecting them in series, was either by actual contact or by the coincidence of lines, as in Svanberg's rods, but as these methods, or any modification of them, are subject to accidental disturbances, Major Colby determined to make the connection visually by means of connecting

microscopes. These, as shewn in Fig. 11, consist each of a central microscope or telescope, as it is called, with a microscope on each side, the lateral microscopes being connected with the central one by a compensation apparatus similar to that of the bar, but so adjusted that the outer focal point of the object glass shall become the compensated point. The object of this arrangement may be understood by the figure 11, which exhibits the telescopes M, M′, in action, either observing the dot on the first point-carrier, as it is called, Y, or transferring the point to the second point-carrier Y′, in the first case commencing, as it were, the measurement from the point where measurement had ended on the preceding day; and in the second, recording on the point-carrier the termination of the measurement of one day, to be taken up on the next in a similar manner. The telescopes admit of a variation of focal length, to a reasonable extent, so as to meet the contingencies of moderately uneven ground, which in this case is presumed to be rising in advance of the higher point, Y′; and it may be observed that it is always desirable to leave a moderate number of point-carriers along the line, especially at points where any difficult piece of ground either commences or ends, so that a re-measurement may be made of any doubtful portion, without the necessity of repeating the whole work. If Fig. 11 be considered the first bar of a new section, and the second or high point-carrier be removed, the bar will be in its proper condition for commencing each succeeding bar being provided with a micros-

only on the further end. The distance between the centres of the two outer microscopes, or the compensation microscopes, is 6 inches, and, of course, the distance from the centre of the inner, or telescopic microscope, to that of either of the others is 3, so that six inches require to be added to the length of every bar used in succession on any one day.

Seven microscopes were used, distinguished by the letters M, N, O, P, Q, R, S, the weight of each being 5lbs. Messrs. Troughton and Simms also constructed two standard measures of 10 feet, formed of bars of wrought iron 122 15 inches long, 1·45 inches broad and 2·5 inches deep, which were placed, like the measuring rods, in boxes, and supported on rollers in a similar manner, to avoid any influence, either from friction or from surface contact, upon the expansion or contraction. These standards were cut away at their ends to half their depth, so as to place the dots about the neutral axis, in order to avoid, as much as possible, alteration of position from flexure. The distance of 10 feet was set off upon these standards, when at the temperature of 62° Fahren-
the terminating points being marked on platina
let into the iron bar, so that all comparisons
required either to be made at that temperature
heir results to be reduced to it. In making any
mparison with that standard, as for example, one with the compensation measuring bar after an interval of disuse, or after any accident, the standard placed on tripods, resting on a wooden frame, was
rought into such a position that the end points

should come into the foci of two delicate microscopes, attached to solid stone pillars, isolated by construction from the surrounding floor; and the microscopes being thus adjusted to the dots of the standard, it was removed, and replaced by the compensation bar, or any other bar requiring comparison, when, should there appear any difference, the amount of it would be measured with the most minute accuracy by the micrometer, forming part of the microscope.

The laborious experiments which were made for comparing the standards with the recognized standards of measure, for determining the exact position of the compensated points of the measuring bars, and for examining various descriptions of varnishes in order to fix upon one which would equalize as much as possible in the two metals the times required for acquiring any change of temperature, (a matter of the utmost importance, as upon that equality depends the perfection of the compensation action, whilst the rapidity of heating and cooling is very different in different bodies,) were carried on by Lieutenant Drummond, assisted principally by Lieutenant Murphy, who died at Bussorah after the successful termination of the Euphrates expedition, but occasionally by several of our little band, under the immediate eye of Major Colby, on the basement floor of the Ordnance Map Office. The result was everything which could be desired, and the base of the Irish survey was measured on the extensive plain at the foot of the Benevenagh mountain, and between it and Lough Foyle, under the immediate direction

of the inventor of the bars, in the summer of 1827, with the most perfect success, several portions of the measurement having been witnessed by some of the most eminent scientific men of the country.

It is to be regretted that Major Colby could not have devoted his time immediately to the publication of the details of this beautiful operation, and have thus connected his own name *alone* with a work so eminently his own; but at the moment the pressure on the survey, as regarded its more immediately practical results, was beginning to be felt, and it is not surprising that he found it necessary to devote his sole attention to the realization of the hopes of the public, by hastening on the more simple topographical work, and the preparation of the 6 inch maps, so urgently required for the use of the Valuation Commission. Yet, making this fair allowance for a first delay in publishing an account of the measurement of the base line, and also for the difficulties imposed upon Major Colby by the removal, first of Lieutenant Drummond, who was called upon by the Government to enter on those political duties which he so ably performed, first on the Reform Boundary Commission, then as Private Secretary to Lord Althorpe, and finally as Under-Secretary in Ireland; and again of Lieutenant Murphy, who was required to take charge of the scientific operations of the Euphrates expedition, under Colonel Chesney, R.A., as these two officers had been more concerned in the preliminary experiments and subsequent operations connected with the measurement than

any others, it must still be admitted that the protracted delay of so many years was due to a constitutional defect in Major Colby's character, as in him, that which in moderation would have been a theoretical virtue of a high order, became, in excess, a practical vice. Major Colby, in fact, thought little of personal distinction, and as he looked upon the publication of maps as the great object of the Irish survey, his attention became concentrated upon it, and, for a time, he almost overlooked that portion of his work which, though of comparatively less importance to the public at large, was *the portion* which would be most welcomed and appreciated by philosophers, and which was most fitted to elevate his character in their estimation. It was thus that whilst the townland survey began to move with giant strides, and to exhibit in all its movements an organization as perfect as that of the most admirably fitted machine, the remembrance of the scientific operations appeared to be gradually fading away into oblivion. Fortunately however the operations on the shores of Lough Foyle had been witnessed by too many men of science to allow them to remain barren of results; and soon afterwards Colonel Everest, then Surveyor General of India, being in England for the recovery of his health, applied to the directors of the East India Company for authority to order from Troughton and Simms a complete set of Major Colby's compensation bars for the use of the Indian survey, and with their usual liberality in all matters connected with

science, the directors immediately assented. The bars were made, taken to India by Colonel Everest, used in verifying several of the preceding measurements, and actually first described by him in his account of those operations. In a similar manner Mr. Maclear, the Astronomer at Cape Town, applied for the use of the bars made for the first survey, to measure a base in Africa, preparatory to the operations for verifying Lacaille's arc, and they were taken to the Cape for that purpose, in charge of the late Captain Henderson, R.E., who had been one of the officers employed in measuring the base on Lough Foyle.

Before, therefore, Major Colby had published any description, however brief, of his measuring apparatus, he had seen it described by another officer of eminent scientific abilities, and employed both in Asia and Africa, in verifying some of the most important arcal measurements which had ever been made, a practical triumph which was probably more congenial to the mind of Major Colby than any personal acknowledgment or testimonial would have been. At length, however, the omission was supplied, and, at the request of General Colby, an account of the measurement of the base on Lough Foyle, including a full description of the apparatus, was published under the immediate superintendence of Captain (now Lieut.-Colonel) Yolland. Though it is impossible not to regret that the inventor of the new measuring bars, and the conductor of the first measurement made with them, should not have pub-

lished a work which describes inventions and operations so pre-eminently his own, yet, at the same time, the omission may be received as a powerful illustration of the total absence of selfishness in that remarkable man. So free indeed was he from that vice of little minds, and so ready on all occasions to recognize and give publicity to the merits and labours of his officers, that many people almost overlooked the commanding officer in their admiration of the subalterns; a feeling, indeed, so strong, that for a long time Lieutenant Drummond was even considered the inventor of the very compensation bars of which he had, at the first, disapproved. Captain Yolland had not himself taken part in the Irish survey, but he had for some years been the executive officer of the Ordnance survey, had superintended the numerous calculations necessary for the task he undertook, and by the able description of the measurement of the Lough Foyle base already alluded to, as well as by the excellent Treatise on "Geodesy," in the third volume of the Academy course, has proved his sound knowledge of the subject, and his ability to support the character of a great National Survey. To these two works my brother officers must refer for further information on subjects which I have here dwelt upon, only so far as was necessary for recording the labours, and delineating the character of General Colby.

The mental activity which was called into action at the commencement of the Irish survey was not exhausted in the one act of invention which has been

described. It became also a question whether the old theodolite should still continue the sole instrument for taking angles, or whether the "Repeating Circle," invented by Borda, and ever since the favourite instrument of Foreign geodesists, or some modification of it, should be adopted in place of the theodolite, or in association with it. In the great theodolite of Ramsden, the accuracy of the great divisions of a large circle of 3 feet in diameter, and the minute subdivision attained by delicate micrometer microscopes, were considered to be the surest means of obtaining accuracy of reading; whereas in the repeating circle, made comparatively small for the sake of portability, the errors of reading were sought to be compensated, or neutralized, by reducing the number of readings, necessary for several observations of the same angle, to two only. For effecting this purpose two concentric circles are used, capable of moving separately or being clamped together, the outer of which is graduated, and the inner carried the verniers and telescope.

In this arrangement the plane of the instrument, when connected with its stand, is brought into the plane of the observer and of the two objects to be observed, and the two circles being clamped together are turned round on the common axis, until the telescope wires bisect the left hand object, the vernier of the inner circle being either at 0°, or at some other definite degree of the outer circle: the outer circle is then clamped, and the inner, being unclamped, is turned until the right hand object is

bisected, when the inner circle is again clamped to the outer circle, and instead of reading the angle, as in ordinary circles or theodolites, the entire circle is unclamped, and the combined circles moved backwards until the telescope again bisects the left hand object; and this operation is repeated as often as may be deemed necessary, the termination of the first measure of the angle becoming the beginning of the second; the termination of the second the beginning of the third, and so on; when at last the angle is read, the telescope finally bisecting the right hand object, and the whole space passed over, which may be either less than 360°, or exceed any number of times the whole 360° of the circle, being divided by the number of moves or repetitions, gives the actual angle between the objects. The errors of reading are thus restricted to the errors of two readings, namely, that at the beginning and that at the end, which become infinitesimal when divided by 10, 20, or more, according to the number of moves, or repetitions, as they are called. The simplicity and beauty of this contrivance immediately gained for the repeating circle many enthusiastic admirers; but our great instrument maker, Troughton, never approved of the principle, and in a Paper in the Astronomical Transactions he expresses his opinion in reference to the defects of this instrument, consequent on the smallness of the telescopes connected with it. "However," he says, "an instrument may be constructed, or in whatever manner it may be used, I have no faith that it can

give results nearer the truth than a quantity that is visible in the telescope," and Mr. Airey, the Astronomer Royal, is considered to concur fully in this opinion, having, indeed, in his Article on the Figure of the Earth, given a decided preference to the Sector, as an instrument for the celestial observations of a great survey. In truth, though the individual or single angles are not read in observations with the repeating circle, but simply the multiple angle, those angles *are observed*, and consequently must introduce the uncertainties or errors due to imperfect observations with an inferior telescope, though correcting or reducing to a minimum the possible errors of reading, consequent on the small size of the circle; and hence the comparison between it and the great theodolite of Ramsden was really between an instrument which corrected the error of reading by the principle of repetition, but left the errors of observation to the chance of mutual compensation, some being + and some —, with an instrument which not only reduced the errors of reading by the use of a large circle capable of the most accurate division, combined with powerful reading microscopes, but also diminished the errors of observation, by the use of a powerful telescope. Under these circumstances, it was not surprising that Major Colby shared the opinion of Troughton, and was not disposed to abandon the great theodolite, which for so many years he had handled with the greatest skill. About this time, however, Mr. Pond, then Astronomer Royal, had prepared

what was called a repeating table, which consisted of a firm iron tripod, supporting, on a collar, a hollow conical axis with three arms at its summit. By this arrangement, the levelling foot-screws of a theodolite being received in grooves or cups fixed to the arms of the repeating table, it became possible, supposing the vertical axis of the theodolite to be in the same vertical line with the axis of the repeating table, to make the repetitions in a very simple manner; but to have effected the adjustment of the axes, supposing an ordinary theodolite to have been placed on a repeating table, would have been a matter of considerable difficulty, and the repeating theodolites which Major Colby ordered to be made on this principle required, therefore, a peculiarity of construction, the principle of which will be better understood on reading the description of the 2 feet theodolite presently to be given. Several of these theodolites, 12 inches in diameter, were made, but though unquestionably capable of doing good work, the general impression was that a mean of a moderate number of angles, taken with the theodolite alone, was fully equal in accuracy to the repeated angle obtained by using the repeating table in the same manner as the outer circle of the repeating circle, and the same was the general impression also in respect to the observations made with a beautiful repeating theodolite by Reichenbach, which was purchased from Bouza, the Spanish Astronomer, then a refugee, and which is the very instrument described by Baron Zach. These instru

ments were destined for the District Triangulation, being the first step of the progression from the great triangulation, (the Division Triangulation being provided with 7 and 8 inch theodolites,) and are, without doubt, very beautiful instruments. The repeating table was applied to a more important instrument, expressly made by Messrs. Troughton and Simms for the use of the Irish survey, and intended to be applied more especially to the triangulation in immediate connection with the base line. In this instrument the divided circle is 2 feet in diameter, and the reading is effected by microscopes attached to strong conical arms which are connected with a central drum, on which rest the pillars which support the horizontal axis of the telescope, and to which the microscopes for reading the divisions of the vertical circles, connected, one on each side, with the telescopes, are fixed. In the interior of the drum is a hollow cylinder, accurately fitted to the vertical axis of the instrument, round which, together with its microscopes, telescopes, &c., it turns. This vertical axis, which is made hollow, occupies the centre of the divided limb or circle, and is connected with it by six brass conical radii to which that circle is firmly attached. The vertical axis, which projects upwards, in order to form the axis of motion of the drum, projects downwards in the hollow axis of the repeating table, and there turns in a separate hollow cylinder, which is kept in its place by centring screws passing through the hollow axis of the repeating table. The levelling

ing table are received in cups
gular iron frame, which forms the
ting wooden stand; and those of
, or more properly speaking, altitude
ment, in cups attached to the arm
table. It will be observed by the
all the vertical axes are made
; of which is, first, to place the
le, after having levelled it accurately,
nometrical point by aid of a mi-
porarily fixed on the upper part of its
is; and when this has been effected, and
dolite placed on the repeating table and
, to place its centre also over the point, by
a microscope screwed into the top of the
and looking downwards through the hollow
of the instrument and table; the adjustment
in the latter case effected partly by means of
hed cylinder within the hollow axis of the
d the centring screws, and partly by the
ng screws of the telescope. This delicacy
nent was necessary in an instrument in-
l to be placed over the delicate referring
of the base, in order to preserve in the angular
rements that minute accuracy for which pro-
had been made in the linear measuring. It
unnecessary to add that in this instrument
um can be clamped to the divided circle, and
manner that the hollow axis of the repeatin
be clamped to the collar of the tripod i
it moves; the circle, therefore, always re-in-

with the repeating table, but the drum and microscopes being capable of independent motion, in this respect differing from the theodolite of Ramsden, in which the microscopes are fixtures, or only moveable with the outer case, which can be turned round on the stand for the purpose of changing, as it is called, the arc, then in fact performing, though rudely, the functions of a repeating table, whilst the divided arc moves round with the telescope, being attached by strong conical radii to a vertical hollow cone, which turns round upon a solid axis. As the focal length of the telescope of this instrument is 2 feet, it evidently unites theoretically the advantages of the large circular instruments of Ramsden and of the repeating circles, providing at once for accuracy of observation by a powerful telescope, and for precision of reading, both by a divided circle of considerable magnitude, and by the use of the repeating principle; if, therefore, it has not fully realised the expectations of its able makers, the result may be considered a confirmation of the other objection urged against repeating instruments, namely, the difficulty of ensuring that perfect concentricity of motion should be at first attained and subsequently preserved, between the moving portions of the instrument and those of the table. Though it is almost impossible to give an adequate idea of this very beautiful instrument without a figure (see Vol. 3 Academy Course, Plate VIII.), this brief description was necessary in order to show that General Colby was fettered by no old prejudices, but endeavoured

to introduce into the Irish survey every supposed improvement which had been adopted by Foreign geodesists, and to give it the fairest possible trial, by applying to its development the unrivalled mechanical ingenuity of Troughton.

Another important consideration was the nature of marks to be used, as objects for observation, and this again called forth all the ingenuity of Lieut. Drummond. The usual objects were conical piles of turf or of stone, 15 or 16 feet high, or staves, formed of planks, 20 or 25 feet high, and sometimes 1′ 6″ wide, which, in peculiarly favourable states of the atmosphere, could be seen distinctly 90 to 95 miles, but long intervals of time would necessarily intervene, when no satisfactory observation could be effected of such distant objects. In the first section of the Memoir has been noticed, the ingenious contrivance of Major Colby, by which he reflected the sun's rays, on a definite line, from pieces of tin nailed on a staff, at angles corresponding with the varying elevations of the sun, and acting, therefore, for some days, as a true heliostat. This was probably the first application of the principle to geodetical operations, but just before the commencement of the Irish survey, Gauss had prepared two forms of heliostat, which were described by Baron Zach, and used in the Hanoverian survey, the account of which was published in 1820, and which as a survey deserves special notice, as the celestial observations for determining the amplitude of the arc were taken with Ramsden's sector, lent for the purpose. Thes-

heliostats were simple and effective instruments, but the reflecting surface was very small, not being intended for use at very long distances. It is by no means certain that Lieutenant Drummond was aware of Gauss's inventions before he had prepared his own, although he was certainly cognisant of them very soon afterwards. In his first heliostat, the direction was determined hy one telescope, which may be called the "pointer," and the motions of a mirror, connected with it by an arrangement of rods or thin bars, something similar to those of a pantagraph, were determined by a small telescope with which the attendant followed the sun, the mirror moving simultaneously with it; so that the rays, when the sun was observed through this telescope, were falling on the mirror in such a manner as to be reflected from it in the direction of the pointing telescope. This was a very effective instrument, but it was troublesome in practice, as it required constant attention, and the position of the attendant, when using the small telescope, was awkward. Lieutenant Drummond therefore replaced it by another much more simple, in which the mirror, from 10 to 12 inches square, was connected with a stand by a ball and socket joint, so as to be readily turned in any direction. The line was now marked out on the ground, which must have been done with any form of heliostat, when intended for reflection to distances of upwards of 100 miles, as no directing telescope suitable for such instruments could have seen objects so remote, and

a small flat brass ring being placed in the direction, at about 20 or 30 feet from the heliostat, the attendant had nothing to do but to move the mirror until the sun's rays illuminated fully the brass annular disc before him, when he was certain that the rays were proceeding in the required direction; and at short intervals of time, when he observed the face of the ring becoming faint, to restore it to its brilliancy by a slight move of the mirror. This simple and effective heliostat was used with great success, at distances exceeding 100 miles, such as from Precelly, in South Wales, to Kippure, in Wicklow; the Keeper, in Tipperary, to Culcagh, in Fermanagh, and was so easy of management that it was put in position, and adjusted at Cnocanafrion, by Mr. James Flanagan, (a very intelligent civil assistant, then attached to the triangulation as a point-fixer) from measured distances, set off on lines to near objects, with which I had furnished him from calculation, a measuring tape and a common mason's level having been all the implements required for an operation apparently so delicate. Cnocanafrion, in Waterford, was thus observed from Bartrigaum, in Kerry, a distance of more than 90 miles. The heliostat was made generally useful by reducing the size of the mirror to a circle of 4 or 5 inches in diameter, when the instrument packed with its directing ring in a leather case, slung over the shoulders of the point-fixer, became portable, and at any station could be screwed on to the top of a stick, not only rendering low and obscure stations readily visible,

but also *identifying* them, a matter of no small importance in extensive surveys, as the point-fixer and the observer took care simultaneously to note and record the time of observation. I have been gratified to observe that this mode of reflecting the sun's rays to a definite point, known to every schoolboy, has been recommended by Mr. Francis Galton, the African traveller, as a useful aid to shipwrecked sailors when struggling on the ocean in a boat, and unable, from its lowness in the water, to attract the attention of passing ships. Without doubt it would be the surest mode of drawing observation on the boat, and for such a purpose a bright piece of tin, or of any polished metal, might, as in General Colby's first contrivance, be used as the reflector.

In addition to the heliostat, Lieutenant Drummond proposed to apply the property of lime, and several other substances, of becoming intensely luminous at a very elevated temperature, the light of lime being especially pure and vivid. This property had been applied before in the laboratory of the chemist, but Lieutenant Drummond had the merit of applying it first to geodetical and lighthouse purposes. The preparatory experiments were carried on, as usual, in the apartments of Lieutenant Drummond, and were watched with the greatest interest by all of us, as well as by several men of science not connected with our profession, amongst whom was the amiable Dr. Prout. Lieutenant Drummond soon perfected his apparatus with the aid of Mr. Simms, the lime being placed in the focus of a parabolic mirror, and

heated by the flame of a spirit lamp, driven upon it by a blast of oxygen gas; and from that time the light has been commonly called the "Drummond Light," and the apparatus "Drummond's Light Apparatus." It was first tried in the long room of the Tower, a room 300 feet long, which was destroyed at the time of the great fire, in comparison with an argand burner of the best description, and Fresnel's lens, lent for the occasion by Mr. Stevenson (the Bell Rock Stevenson); and again at the Trinity House and at Purfleet. Captain Basil Hall thus describes a portion of these experiments, which he witnessed from the Trinity Wharf, Blackwall, in a letter to Lieutenant Drummond, who being at Purfleet directing them, could not himself observe the effect. "The next series of experiments was the most interesting and decisive of all: each of the lights above enumerated, viz., the single argand burner, the seven argands, and the French lens, were exposed, one at a time, in company with your light, in order to try their relative brilliancy.

1st. In respect to the single argand, nothing could be more pitiable than the figure it cut, being scarcely visible, and of a dusky orange tinge, while your light was of the most intense whiteness.

2nd. In respect to the seven argands combined, they were certainly easily visible, but I should not hesitate to say that your light was at least six or eight times as conspicuous, while in brilliancy or purity, or intensity of light, the superiority was even more remarkable.

3rd. As regards the French lens and your light, the superiority was equally undeniable, though the difference in the degree of whiteness was not so remarkable; the French light, however, is so nearly similar to that from the seven argands, that the comparison of each of them with your light gave nearly the same results, and all equally satisfactory, on the score of your discovery."

For some time it was hoped that the Drummond Light would be adopted in our light-houses, but the practical difficulties, involving the manufacture of oxygen gas, has hitherto prevented the realization of this hope. On the survey it was used only at one station, Slieve Snacht, in Innishowen, which had baffled (probably in consequence of its position so near to Lough Foyle, over the surface of which the visual rays passed) the observers at Divis, near Belfast, for the whole season, though the distance between the two stations was little more than sixty miles. On the top of this mountain, amidst the snows and intense frost of the severe November of 1825, Lieutenant Drummond established himself, manufactured his oxygen gas, put up his apparatus and exhibited his light, which at once dispelled the difficulty of the observers, as it was visible even in the daylight, and shone at night with planetary brilliancy and distinctness.

In addition to these various appliances, the plan which had been shortly before proposed by Baron Zach, as the means of obtaining great accuracy from a very small portion of actually measured base, was

likewise adopted, both for the purpose of comparing successive portions of the measured base with each other, and for adding on to the measured base a portion which, extending over the uneven surface of the Magilligan Sands, could not have been measured with the same certainty of precision. This method consisted in turning over by triangulation, as it were, a measured piece of the base on the line prolonged, or of comparing in a similar manner one measured portion with another immediately following it. Taking the latter as an illustration, the method of proceeding is this : let ABC be a portion of the base measured, and AB = BC, now placing the theodolite, or altitude and azimuth instrument, at B, set off two perpendiculars on AB, one on each side, and as nearly as possible equal to AB, namely BD and BD′, then observing at A the angles BAD, BAD′, and at D and D′ the angles ADB, CDB, AD′B, CD′B, and further at C, if desired, the angles BCD, BCD′, the actual lengths of the perpendiculars BD, BD′, may be determined from AB, as a base, with great precision, and thence BC from BD and BD′ with equal precision. Many such comparisons were made during the measurement of the base, and were very satisfactory in their results : and in a similar manner the portion of the Magilligan end was added on to the measured base.

The subject also of the disturbing effect of unequal local attraction, due to variation in the density of the superficial crust of the earth, on the observation of zenith distances was not overlooked, General

Colby having supported the geological examinations of Dr. Macculloch in Scotland, which were in part intended to facilitate the estimation of such attractions, and having, as pointed out in the first part of this Memoir, succeeded in determining the amount of error in some of the amplitudes which was strictly attributable to such a cause. Had he continued connected with the survey he would undoubtedly have persevered in such enquiries, and they have not been neglected by the present Director of the survey, who has directed the attention of the department to the determination of the local attraction of Salisbury Crag. The results of this investigation have been most ably calculated and analyzed by Captain A. Clarke, R.E., one of the survey officers, in a valuable paper read before the Royal Society, and which will be hereafter published in the survey records. Two remarkable papers in the Philosophical Transactions for 1855 will doubtless not be overlooked by Captain Clarke, in his investigations of this important subject, on the right understanding of which so much of the accuracy of arcal determinations must depend. In the first, by the Venerable Archdeacon Pratt, of Calcutta, on the attraction of the Himalaya Mountains, and the country beyond them, on the plumb-line, in India, it is shewn that, whilst the amplitude of the northern division of the arc, included between Kaliana and Kaliampur, as determined by astronomical observations at the two extremities, is 5° 23′ 37″·06, when computed geodetically, on the usually admitted form of the earth, it is 5° 23′42″·29,

the astronomical arc being in defect of the geodetical by 5″·23. It is next shown that the simple *geodetical* measurements could not be materially affected by mountain attraction; and attention is then directed to the determination of the actual amount of attraction of the masses supposed to operate on the plumb-line in India; but for the ingenious methods adopted by Mr. Pratt, of dividing the country into compartments in relation to each point of comparison, arranging the space, called by him "Enclosed" space, and comprising all the compartments considered capable of exercising a perceptible action, into the "Known Region" and the "Doubtful Region," and estimating from the recorded and actual data of the first, and from the best published accounts of the latter, their respective masses, and hence their attractive forces, reference must be made to his paper, or to the abstract of it, in the Astronomical Society's proceedings. The results of the calculations would give a deflection at the northern, middle, and southern stations, called A,B,C, of 27″·853, 11″·968, 6″·909 in meridian, and of 16″·942, 4″·763, 2″·723 in azimuth, so that the difference of meridian deflection between A and B is 15″·885, and between A and C 20″·944, quantities greatly exceeding the error of 5″·236. After trying the effects of various hypothetical assumptions, Archdeacon Pratt was still unable to do away with the difference between the observed and the computed deflections, the latter still remaining in excess. At this point then the subject is taken up by the Astronomer Royal, in the

Second Paper, in which he is necessarily obliged to found his reasonings on a hypothetical assumption, namely that the crust of the earth is about 10 miles thick, and rests on a fluid mass, called, for convenience sake, lava, more dense than itself. He then states that the effect of the pressure of a high table land, 2 miles thick and 100 miles across in its horizontal dimensions, resting on the earth's surface, would be to crack the crust below, and force the edges of the fracture into the lava beneath, so that, whilst the attraction above the crust would be increased, the attraction below would be diminished by the exchange effected between the heavier matter of the lava and the lighter of the crust forced into it. From this investigation, Mr. Airey comes to the general conclusion that the real disturbances will be less than that found by computing the effect of the attraction of the mountains, the differences in all cases being small at points near the elevated land, but very great, indeed, or nearly equal to the whole, at distant points. Let it be added that these ideas of the Astronomer Royal are of high interest in their bearing upon many most important geological questions.

The only other instance I shall quote of General Colby's anxiety to render the Irish survey perfect in all its branches, is the judicious manner in which he supplied the place of the celebrated 9 feet sector of Ramsden, which had been destroyed in the great fire which ravaged the Tower. The fault of that admirable instrument was its want of reasonable

portability, as, in consequence, it became necessary to restrict the number of places of observation, and it was scarcely possible to shift the sector about in the manner required for testing the effect of local disturbing attractions. In this respect, then, the repeating circle had a decided advantage, and Colonel Colby being therefore anxious, in replacing the old sector, to adopt a construction of instrument which should retain the advantages of the sector, and yet share with the repeating circle in the advantage of portability, turned to the Astronomer Royal for advice and assistance in planning the new instrument.

In the Preface appended by Colonel Hall, R.E., then Superintendent of the Ordnance Survey, to Captain Yolland's account of the "Astronomical Observations made with Airey's Zenith Sector," published in 1852, the subject of this new instrument is thus noticed: "to the Astronomer Royal this department is deeply indebted for the valuable advice and assistance afforded by him on numerous occasions, both with reference to the use of the instrument, and the reductions of the observations; and is wholly indebted to him for the design and superintendence of the construction of the instrument; for in the Autumn of 1841, Major-General, then Colonel, Colby, R.E., my predecessor as Superintendent of the Ordnance Surveys, seeing the necessity for obtaining accurate latitudes of some of the mountain stations used in the principal triangulation of the United Kingdom, consulted the Astronomer Royal, G. B. Airey, Esq., with reference to the construction of a Zenith Sector, of a more portabl

description than Ramsden's, and of such a nature that observations made with it on a single night might be expected to furnish absolute zenith distances with great accuracy, instead of being dependent on observations made with an instrument usually placed in reverse positions on successive nights, or as frequently as the nature of the weather would permit; and the Astronomer Royal, with his usual readiness to oblige, gave the subject his immediate attention, and accordingly proposed and subsequently superintended the construction of the instrument with which the observations recorded in this Volume have been made." The instrument is fully described by Captain Yolland, in the Volume to which reference has been made. The material used was principally cast iron, and the instrument was formed of as few parts as possible, each being cast in one piece, so as to avoid that pregnant source of deterioration sure to be found in numerous parts, each formed by the union of many pieces. The rectangular revolving frame, which carries the divided limb, is of gun metal, cast in one piece; the telescope frame, also of gun metal, bears on a circular ring 9¼ inches in diameter, attached to the centre of the frame, and turns on a hollow circular pivot which passes through a corresponding circular hole 3½ inches in diameter in the centre of the frame. The divided limb consists of two arcs, each of 45°, placed 20½ inches from the centre of the frame, so as to form parts of a circle 41 inches in diameter, reading from 0° to 360°, the divisions being on silver. The focal length of the telescope is 46

inches, the diameter of the object glass 3¾ inches, and the magnifying power usually employed 70; the microscopes for reading the zenith distances are attached to the telescope frame. The revolving frame turns in azimuth on a vertical axis, formed by two conical pivots, connected with the external frame, one above and one below, and the telescope frame turns vertically on the horizontal axis before noticed, so that the work of reading, turning the instrument 180° in azimuth, and reading again, is effected with great ease and rapidity. In addition to this, the upper pivot of the revolving frame can be raised upwards by a screw, and the whole frame can be reversed, end for end; the divided arc, which was at first below, becoming then the upper arc. Instead of the plumb-line of the old sector, spirit levels, supplied with very accurately divided scales, were used in this instrument, of which the total weight was nearly 10¼ cwt. The system of clamping has not here been detailed, but so simple and perfect was everything connected with it, that in the hands of the officers of Engineers, and non-commissioned officers and privates of the Royal Sappers and Miners, (soon about, it is hoped, to share our name of "Engineers," as they have so long shared our labours and our dangers) a mass of accurate observations has been collected, such as perhaps no other survey in the world can boast of.

Let me here express an opinion and a hope, which I trust, may attract the attention of some scientific member of Government, and lead to the re-

alization of that hope. The bases of our own survey, the bases of the Indian survey, and the South African base, have now been verified in the most scrupulous manner by new measurements with the compensation bars, and the observations for latitude in our survey have been verified with Airey's Sector; surely then it would be worthy of Europe and America to encourage a similar verification of their own bases and their own observations for latitude, with the same instruments. The compensation bars and the zenith sector of Airey could be carried with ease to France or any other part of Europe, to Asia and to America, and having been used in verifying the old work, the comparison of arcs would be no longer made from measurements and observations effected by so many different instruments, but would depend on data in every respect harmonious and consistent.

To enable us to form a correct estimate of the scientific claims of General Colby, it may be well briefly to sum up, under two heads, the services by which it is considered that he materially advanced the progress, and raised the character of the British survey. 1st. When serving under General Mudge, he displayed that extraordinary degree of mental and physical energy, of endurance of fatigue, and of perseverance, which gave new life to the survey. whilst in all its operations he exhibited a remarkable skill in observing, which called for the admiration of foreigners, and was well known,and admitted to be first rate, by its own officers. 2nd. When at the head

of the survey, he gave a new character to its scientific branch, by the invention or application of new instruments, he planned and matured an admirable system for the more practical portion; he took the highest view of the objects of a survey, looking upon it as the basis for National Improvement, and consequently as the groundwork for Historical, Antiquarian, Natural History, Geological and Statistical Surveys, having thus commenced what his former able assistant, Lieut.-Colonel Larcom, has since perfected in the Statistical Tables prepared under his directions, as Under Secretary for Ireland; he encouraged the formation at the survey office, not merely of a Museum of Economic Geology, but of a Museum of General Natural History, recent and fossil, and though under the influence and by the ability of Sir Henry De la Beche, the Museum of Economic Geology has since become a National Institution, and a National Triumph, it should not be forgotten that the Phœnix Park exhibited previously the germ of such an establishment; he endeavoured in every way to improve the artistic character of the maps, and he advocated the contour system, which sooner or later will overcome prejudice, and be adopted generally, with the same successful effect as that which has been so admirably attained by Mr. Mylne, in his Map of the Environs of London. He was wise enough to know that such labours required the co-operation of men of great ability and perseverance, and the names mentioned in this Memoir prove that he exercised an admirable

judgment in their selection; he was also generous enough not to use persons merely as instruments to elevate himself, but kept their scientific reputation equally, if not more, in view than his own. Can it then be doubted that he has an equal, if not a higher claim upon our respect and admiration than any of the remarkable men who have been connected with the survey?

A careful consideration of the facts which have been here adduced will justify us in dividing the History of the Survey into two great periods; namely, that of General Roy, which includes the time during which he, Colonel Williams, and General Mudge presided over it, and that of General Colby, which extended up to the present time; as the inventions and arrangements of Roy and Colby are characteristics of the epoch assigned to them. In the first part of the Memoir I have designated General Roy as an *Artillery* Officer, but in this I was not correct; and having since obtained some valuable information on the subject from Mr. Marriott, the Manager of the Engineer branch of Cox's agency, so well-known to every member of the corps for the uniform kindness and consideration he has ever manifested, as well to the youngest as to the oldest officer, I think it right to render my Memoir of the able first leader of the survey complete by inserting it, more particularly as the information is of general interest to the corps.

The French Corps du Génie was first called into being by the great Sully, the Minister of Henry IV., and was composed of the most able officers which could

be collected together for that purpose; and the British Corps of Engineers was first formed in a similar manner in 1757. Before this time there had indeed been a corps of Engineers, but, like that of Military Draughtsmen, it consisted of *Warrant* Officers. William Roy was one of those selected for the new corps, having already belonged to the previous corps, as his name appears as Practitioner-Engineer in the Army List of 1756. He became Practitioner-Engineer and Ensign of the New Corps of Engineers, May 14, 1757; Sub-Engineer and Lieutenant, 17th March, 1759; Engineer in Ordinary and Captain, also in that year; but there appears some confusion as to the precise date. The date of the intermediate step, if he ever held it, of Engineer-Extraordinary and Capt.-Lieutenant, is not known. He was Director and Lieut.-Colonel of Engineers, 1st of January, 1783; Director and Colonel, 16th September, 1785. In the Army he was Lieut.-Colonel, 23rd July, 1762; Colonel, 29th August, 1777; Major-General, 19th October, 1781. He was Deputy Adjutant-General in 1764, 1765; Deputy Quartermaster-General in 1766, and was appointed Colonel of the 30th Foot, 15th November, 1786. This statement is of the highest importance at the present moment, as it indicates the high estimate which was originally formed of the qualities which an Engineer officer ought to possess. They were indeed in the first instance, and for many years afterwards, as in France, selected from the Artillery and from any other quarter where high intelligence had been manifested,

as may be well illustrated by the case of George Morrison, who was Lieut.-Colonel in the Army and Quarter-Master-General in 1761, but became Engineer in Ordinary and Captain of Engineers in 1766; and, after attaining the Engineer rank of Major and Sub-Director, left the Corps, and as Major-General, became successively Colonel of the 17th and 4th Regiments of the Line. They were, in the cases of General Roy and of several other of the earlier officers, employed in the most confidential posts of the General Staff of the Army, and even promoted to the command of Regiments of Infantry. The teaching of such experience ought not to be thrown away, as it will certainly be found hereafter that should an attempt be made, either to amalgamate the Artillery and Engineers, or to deprive the latter of their high military character, the immediate result will be a practical disappointment, and the future result a restitution of the corps to all its individuality and intellectual pre-eminence. General Roy was selected as first director of the survey, not because he was an officer either of Artillery or of Engineers, but because he was a man of well-known scientific abilities; his successors, Colonel Williams and General Mudge, were officers of Artillery, but they, too, were selected for their supposed fitness, not for their Army position; and in like manner Captain Colby, an officer of Engineers, was selected because the Duke of Wellington, assisted by the opinions, not of Heads of Military Departments, but of scientific men, considered him the best man

or such an office. The survey was then an independent work, and General Colby being, as its director, responsible only to the Master-General, thought himself justified in requiring the services of officers of Artillery, as well as of officers of Engineers, and, in consequence, for several years he employed on the Irish survey the late Lieutenant-colonel Robe, R.A., a most able surveyor, and also lieutenants Rogers and Mallock; but he was soon obliged to restrict himself to officers of Engineers, as the authorities of the Artillery declared they would not spare their officers for such a service, and required them to return to their ordinary duties.

The more complete military organization which Colonel Colby proposed for the Irish survey, and the consequent employment of a large body of Sappers, gave a new character to the Survey Establishment, and ultimately led to its absorption into the general body of the Engineer Department. The loss of that independence, and of the dignity which naturally belonged to the head of a department at once so important, so scientific, and so totally unconnected with ordinary military duties, was unquestionably severely felt by Colonel Colby; but he continued to superintend the survey until he became a general officer, when the ordinary rule of the Engineer Department was applied to his case, and as it is technically called, he was put upon the shelf, and replaced as superintendent by another officer who had never before been employed in the survey. With the

warmest attachment to my own corps, as a body of scientific officers, for it is only as such that it can ever hope to maintain its high position, and with the sincerest respect for the able officer who presides over it as Inspector General, I have never been able to think that the change in the character of the Survey Department was a judicious one; and I sincerely hope that it will now regain its independence, and enlist in its service the most able officers, whether of the Artillery, of the Engineers, or of the Line (for there is now no separate Ordnance Department) which can be found; and should there be any difficulty in effecting this restoration without still further change, let officers and men be classed together as Staff or Topographical Engineers, with rank and pay commensurate with the importance of their duties: and let the superintendent or chief be selected, as in former times, without reference to his peculiar corps, on the simple ground of recognized abilities, thorough knowledge of the science of geodesy, and fitness of character as regards energy and judgment, to conduct so great a work. I doubt not that my brother officers will generally attain this high prize of intellectual and moral eminence; but it is only as being deserving of it that I can wish to see them obtain it.

In the preceding pages I have, perhaps, said enough to pourtray the frank simplicity, the genuine, as being unostentatious, hospitality, the silent charity of General Colby, who, dreading the charge of weakness, gave secretly what he denied

openly: but I am now enabled, from the following anecdote communicated to me by Lieutenant-Colonel James, R.E., the present Superintendent of the survey, to show that General Colby was also capable of exhibiting a noble munificence in his generosity. Whilst examining the Orkney and Shetland Islands, and selecting amongst them stations for the triangulation of the United Kingdom and for fixing the northern extremity of the British arc of meridian, as detailed in the first part of this Memoir, he was necessarily indebted to Lieutenant Thomas, R.N., then in charge of the hydrographical survey of those islands, in whose vessel he was conveyed from island to island, for most valuable assistance and for the greatest attention and hospitality. Services such as these, in a country so dreary, and in an ocean so stormy, were not only personally agreeable, but were essential to the successful performance of an arduous duty; and so deeply were they felt and valued by General Colby, that he presented Mrs. Thomas with the sum of £500 to assist her husband in the prosecution of a lawsuit in which General Colby had heard that he was then engaged. Lieutenant Thomas, on learning the circumstance from Mrs. Thomas, insisted on returning the money to General (then Captain) Colby; but he did not the less appreciate the noble spirit which had dictated the gift, nor fail to hand down the memory of it to his son, the present Lieutenant Thomas, R.N., who is now, in succession to his father, employed in the North and East of Scotland, and by whom the

knowledge of this interesting fact was communicated to Lieutenant-Colonel James.

In the preceding narrative, General Colby has been generally, though not always, spoken of according to the rank which he held at the time of the event or act recorded; and it is therefore necessary to give a brief statement of the successive changes in his military position, in order to link together the several parts of the Memoir. His entrance into the Engineers, as Second Lieutenant, was in December, 1801; he attained the rank of First Lieutenant in 1802, that of Second Captain in 1807, and that of Captain in 1812; he became Major (by Brevet) in 1821; in 1825 he was promoted to the rank of Lieutenant Colonel, in 1837 to that of Colonel, and in 1846 to that of Major General. During the time thus passed over in review, several changes took place in General Colby's residence: at first he continued to reside at the Ordnance Map office in the Tower, having appointed a local Director to represent him in Dublin, but it soon became evident that the new work required his personal presence more than the old; he therefore assumed the command in person, in Ireland, in 1828, and for ten years steadily directed the operations of the survey, from the Head Quarter Office, at Mountjoy House, in the Phœnix Park, the organization of which he had, with his usual forethought and judgment, confided to Lieutenant Larcom (now Lieut.-Colonel), whom he had taken over with him for that purpose.

In 1828 he married Elizabeth, daughter of the late Mr. Boyd, of Londonderry, for many years the highly respected Treasurer of that county, and took a house in Merrion Square, where, being received as an inmate, after the Hill season of 1829, I had an ample opportunity of seeing him at his own fireside, and recognizing in him those domestic qualities which made every one happy and at ease about him; and I may add also that in Elizabeth Boyd he found a helpmate worthy of him; one, indeed, who, by her simple and unaffected kindness, proved that she entered fully into her husband's feelings, and made his friends her own. General Colby then took on lease Knockmaroon Lodge, close to the gate of the Phœnix Park, and at the distance of a short walk from the office. Here, again, I was a visitor at his house, and saw the virtues of a warm heart still further expanded, as the General had then become a father. My friend Lieut.-Colonel Larcom has said that though General Colby was like a rock, immoveable in a determination on points of duty when he had once decided, he was as gentle and kind as a father or brother when personally communicating with his officers and men; but to see and appreciate those qualities in the highest degree, it was necessary to study them in his own house, where the steady calm reasoner of one moment became, in the next, almost the giddy boy, when playing joyously and without restraint with his children; for, in truth, his greatest happiness was found in the quiet enjoyment of his own home.

It was during this residence in Ireland that he endeavoured to renew the project of a complete Hill-Drawing Department, for which purpose he availed himself of the unrivalled skill in that branch of work of Lieutenant (now Lieut.-Colonel) Dawson. The object appeared to have been fully gained, when, at the moment of success, Lieutenant Dawson was, as in the cases of Drummond and Murphy, removed from the survey, and appointed to an office of great responsibility in England, first in connection with the Reform Commission, and then with that for regulating the Tithes. This department was, however, re-modelled, and rendered even more effective by the introduction of the system of contours. In 1838, General Colby returned to England as the development of the Scotch Survey then began to require his more immediate attention, and in 1846, just at the moment when the map of *the last Irish county* had been given to the public, he quitted the direction of the work and retired into private life.

In respect to his connection with learned Societies, he was one of the original Fellows of the Astronomical Society, having assisted in framing the rules for its government at the period of its formation in 1820, and he succeeded General Mudge as a Member of the Government Board of Longitude. He was a Fellow of the Royal Societies of London and Edinburgh; and of the Geological, Geographical, and Statistical Societies of London; a Member of the Royal Irish Academy, and of the Geological and

Zoological Societies of Dublin; an LL.D. of the University of Aberdeen, and a Knight of Denmark; and as regards the Institution of Civil Engineers, the words of its able Secretary, Mr. Charles Manby, will best show the estimation in which he was held by our civil brethren. "He became connected with this Institution, as an Associate in 1820, and was transferred to the class of Honorary Members in the same year. He was much attached to many Members of the Society, very frequently attended the meetings, took part in the discussions, was always ready to afford information or assistance, and at every annual meeting the Council had the pleasing task of recording General Colby's unceasing attention and liberality, in procuring for and presenting to the Library, the Ordnance Maps, and many other valuable documents, as soon as they were published."

On quitting the Survey, he retired to the Continent and devoted himself to the education of his sons, residing partly in Germany and partly in Belgium, but at length the unsettled aspect of affairs abroad induced him to return home, when with little or scarcely any warning, the Spirit, yet active, was summoned from the Body, yet firm and hale, and on the 2nd October, 1852, in the 69th year of his age, whilst amidst his loving and mourning family, at New Brighton, near Liverpool, he passed from the scene of so much bodily and mental exertion to rest and peace eternal.

Whilst living, General Colby received none of those honourable distinctions which so many prize

far above pecuniary emolument; but it is gratifying to think that the Government has, since his death, recognized his great claims on the Public, and awarded to his widow a life pension.

My task is now completed, and I hope that I have been successful in setting before my brother officers a faithful picture of the services and character of a man who so long and so ably conducted the great surveys of this country. In my early connection with the Irish survey I was his chosen assistant and confidential adviser, and it was then I learnt to appreciate his accurate knowledge, his sound judgment, his untiring energy and consummate skill, and above all, his unbounded liberality in imparting to me and others the stores of his own knowledge. In the later period of my connection he was estranged in feeling towards me; but as I now look back at the past from a more distant point of view, I cannot doubt that there were faults on both sides. In short, I was once his favoured disciple, and feeling that the early kindnesses and services I received from him far outweigh the later harshness, which at the time I deemed injustice, I am proud to have had the opportunity of recording my respect for the memory of a man towards whom, when living, I had always felt and expressed affection.

J. E. P.

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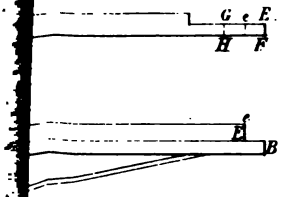

FIG. 8.

FIG. 7.

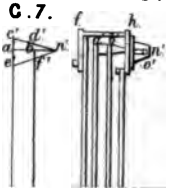

FIG. 9.

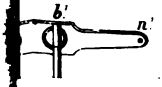

FIG. 10.